NOVEMBER 1971

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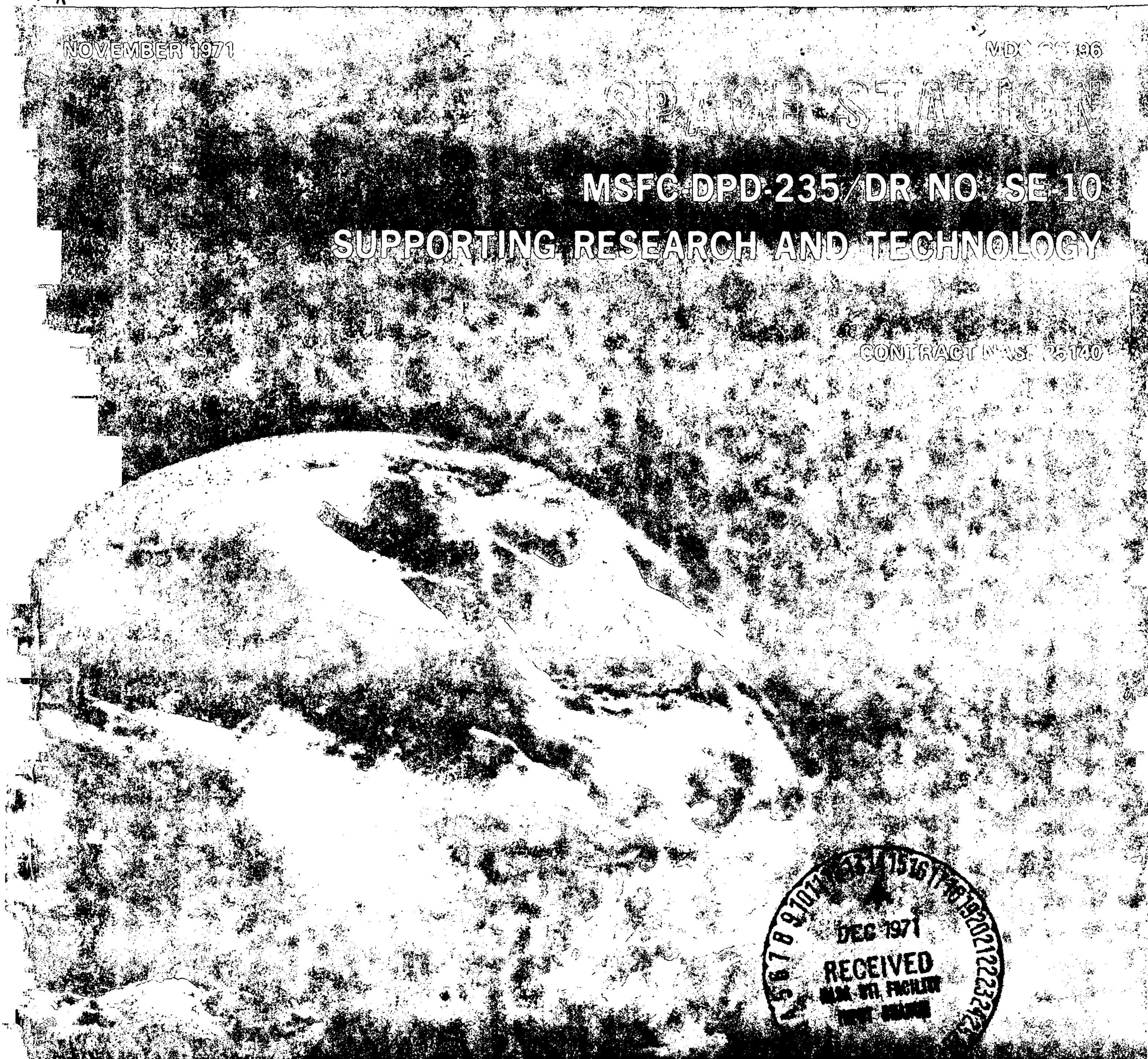
SPACE STATION

MSFC-DPD-235/DR NO. SE-10

SUPPORTING RESEARCH AND TECHNOLOGY

CONTRACT NAS8-25140



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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

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CONTRACT NAS8-25140
MSFC-DPD-235/DR NO. SE-10

SUPPORTING RESEARCH AND TECHNOLOGY

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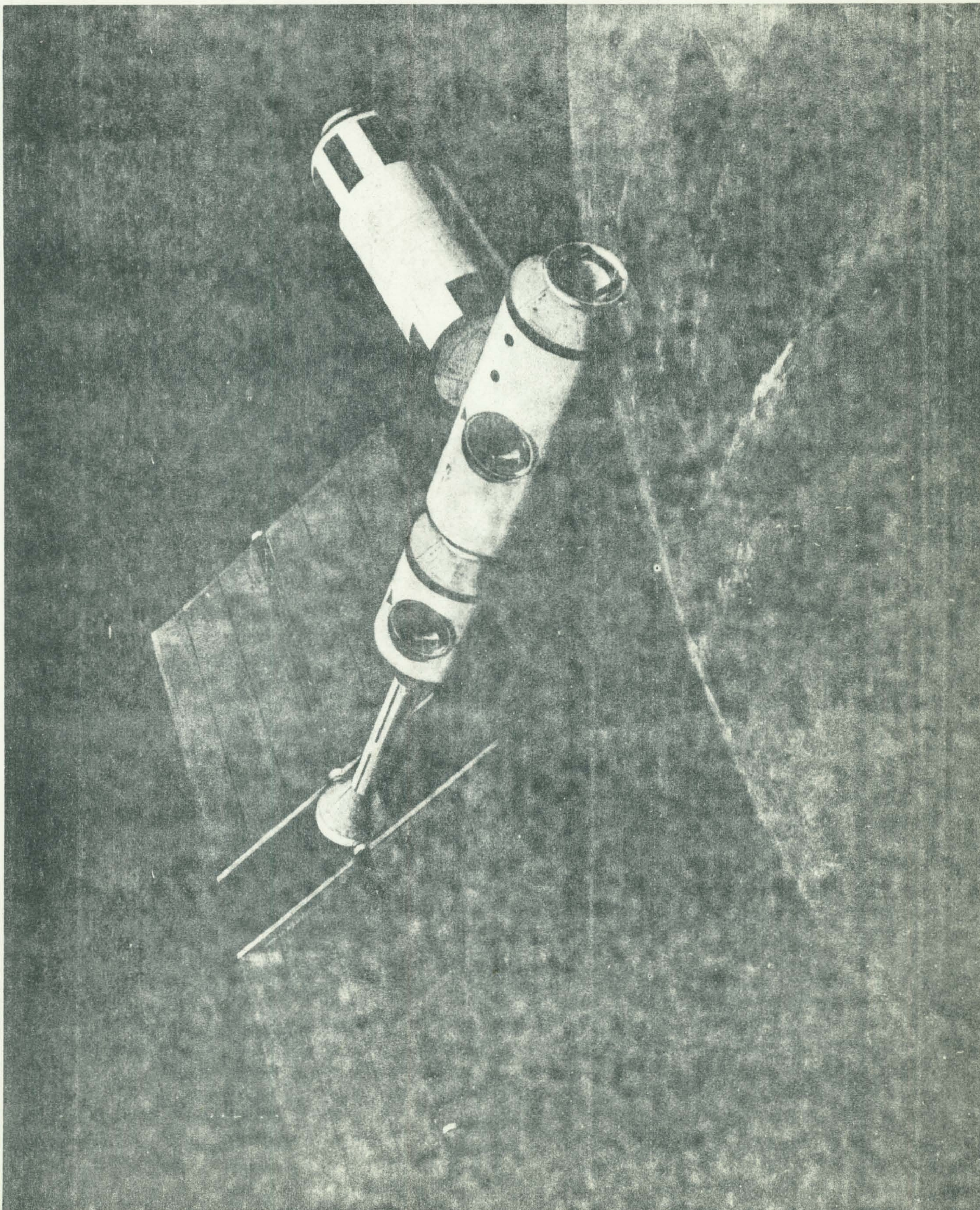

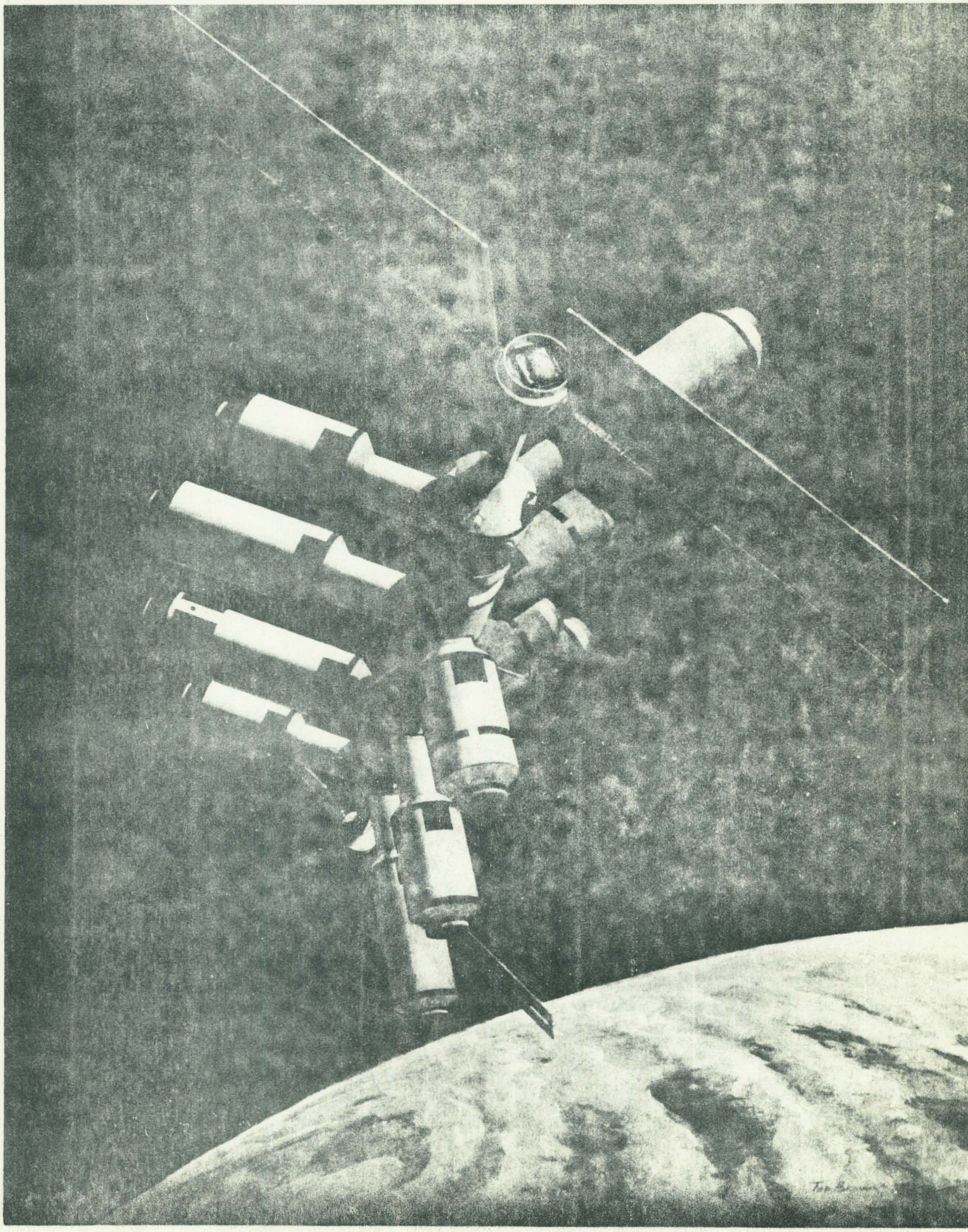

PREFACE

The work described in this document was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the extension period has been to develop the Phase B definition of the Modular Space Station. The modular approach selected during the option period (characterized by low initial cost and incremental manning) was evaluated, requirements were defined, and program definition and design were accomplished to the depth necessary for departure from Phase B.

The initial 2-1/2 month effort of the extension period was used for analyses of the requirements associated with Modular Space Station Program options. During this time, a baseline, incrementally manned program and attendant experiment program options were derived. In addition, the features of the program that significantly affect initial development and early operating costs were identified, and their impacts on the program were assessed. This assessment, together with a recommended program, was submitted for NASA review and approval on 15 April 1971.

The second phase of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

A subject reference matrix is included on page v to indicate the relationship of the study tasks to the documentation.

This report is submitted as Data Requirement SE-10.

DATA REQUIREMENTS (DR's)
MSFC-DPD-235/DR NUMBERS
(Contract NAS8-25140)

Category	Designation	DR Number	Title
Configuration Management	CM	CM-01	Space Station Program (Modular) Specification
		CM-02	Space Station Project (Modular) Specification
		CM-03	Modular Space Station Project Part 1 CEI Specification
		CM-04	Interface and Support Requirements Document
Program Management	MA	MA-01	Space Stations Phase B Extension Study Plan
		MA-02	Performance Review Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase C/D Program Development Plan
		MA-06	Program Option Summary Report
Manning and Financial	MF	MF-01	Space Station Program (Modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternate Bay Sizes

FOLDOUT FRAME 1

FOLDOUT FRAME 2

SUBJECT REFERENCE MATRIX

LEGEND:
- CM Configuration Management
- MA Program Management
- MF Manning and Financial
- MP Mission Operations
- SE System Engineering and Technical Description

	CM				MA		MF	MP			SE								
	CM-01 Space Station Program (Modular) Specification	CM-02 Space Station Project (Modular) Specification	CM-03 Modular Space Station Project Part 1 CEI Spec	CM-04 Interface and Support Requirement Document	MA-05 Phase C/D Program Development Plan	MA-06 Program Option Summary Report	MF-01 Space Station Program (Modular) Cost Estimates Document	MP-01 Space Station Program (Modular) Mission Analysis Document	MP-02 Space Station Program (Modular) Crew Operations Document	MP-03 Integrated Mission Management Operations Document	SE-01 Modular Space Station Concept	SE-02 Information Management System Study Results	SE-03 Technical Summary	SE-04 Modular SS Detailed Preliminary Design	SE-06 Crew/Cargo Module Definition Document	SE-07 Modular Space Station Mass Properties Document	SE-08 User's Handbook	SE-10 Supporting Research and Technology	SE-11 Alternate Bay Sizes
2.0 Contractor Tasks																			
2.1 Develop Study Plan and Review Past Effort (MA-01)																			
2.2 Space Station Program (Modular) Mission Analysis								●											
2.3 Modular Space Station Configuration and Subsystems Definition														●					
2.4 Technical and Cost Tradeoff Studies							●												
2.4.4 Modular Space Station Option Summary											●								
2.5 Modular Space Station Detailed Preliminary Design														●					
Mass Properties																●			
2.6 Crew Operational Analysis									●										
2.7 Crew Cargo Module															●				
Mass Properties																●			
2.8 Integrated Mission Management Operations										●									
2.9 Hardware Commonality Assessment													●						
2.10 Program Support					●														
2.11 Requirements Definition																			
Space Station Program (Modular)	●																		
Space Station Project (Modular)		●																	
Modular Space Station Project–Part 1 CEI			●																
Interface and Support Requirements				●															
2.12 Plans					●														
2.13 Costs and Schedules							●												
2.14 Special Emphasis Task Information Management (IMS)												●							
Modular Space Station Mass Properties																●			
User's Handbook																	●		
Supporting Research and Technology																		●	
Technical Summary													●						
MOD 29																			●
MOD 40						●													

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CONTENTS

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FIGURES

TABLES

Section 1
INTRODUCTION

1.1 BACKGROUND

With the advent of the Space Shuttle in the late 1970's, a long-term manned scientific laboratory in Earth orbit will become feasible. Using the Shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community and will make available to the United States a platform for application to the solution of national problems such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12, has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Space Station comprised of smaller, Shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as on the 33-foot-diameter Space Station—but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by adding modules and crewmen on a flexible schedule.

The Modular Space Station Phase A—level study results are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is a volume.

The Space Station will provide laboratory areas which, like similar facilities on Earch, will be designed for flexible, efficient changeover as research and experimental programs proceed. Provisions will be included for such functions as data processing and evaluation, astronomy support, and test and calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program.

The Initial Space Station (ISS) will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the Shuttle Orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip Shuttle flights using Logistics Modules (Log M's) for transport and on-orbit storage of cargo. Of the four Log M's required, one will remain on orbit at all times.

Experiment modules will be delivered to the Space Station by the Shuttle as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen, and wastes.

The ISS configuration rendering is shown in the frontispiece. The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General Purpose Laboratory (GPL) Module. This configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (shown in the frontispiece), which will house a crew of 12 and provide a capability equivalent to the 33-foot INT-21 launched Space Station. GSS logistics support will use a Crew Cargo Module capable of transporting a crew of six.

During ISS operations, five Research Applications Modules (RAM's) will be assembled to the Space Station. Three of these will be returned prior to completion of the GSS. In the GSS configuration, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules.

During the baseline 10-year program, the Space Station will be serviced by Shuttle-supported Logistics Module or Crew Cargo Module flights.

1.2 SCOPE OF THIS VOLUME

A Module Space Station supporting research and technology (SRT) program must be established to preclude a relatively high degree of performance or development risk at the outset of Phase D development. The SRT requirements describe the work needed to solve the problems associated with hardware development. Identification of these requirements as they relate to accomplishment of the overall program comprise the subject of this report.

The SRT requirements described in this document are only for the Space Station Project (baseline configuration) of the Space Station Program (Modular). The program milestones and the SRT phasing in relationship to these milestones is illustrated in Figure 1-1. In some cases, due to the particular design solution, the SRT requirements are the same or similar to those for the 33-foot Space Station Study which was covered in DRL 18, Volume IV, "Integrated SRT Plan," dated August 1970. These requirements have been included in this document for completeness.

The SRT items have been classified into categories and technology areas/panels. The definitions of the categories—research, advanced technology, advanced development, or supporting development—are included in this report. This categorization resulted in the definition of 9 items in advanced technology, 71 items in advanced development, and 8 items in supportind development. Estimated total cost is $83 million. Within each category, the items were further categorized into technology areas/panels; i.e., power, information systems, materials and structures, control, bioresearch, bioengineering, or bioenvironmental. These areas and panels have been identified, defined, and described in terms of the type of SRT applicable.

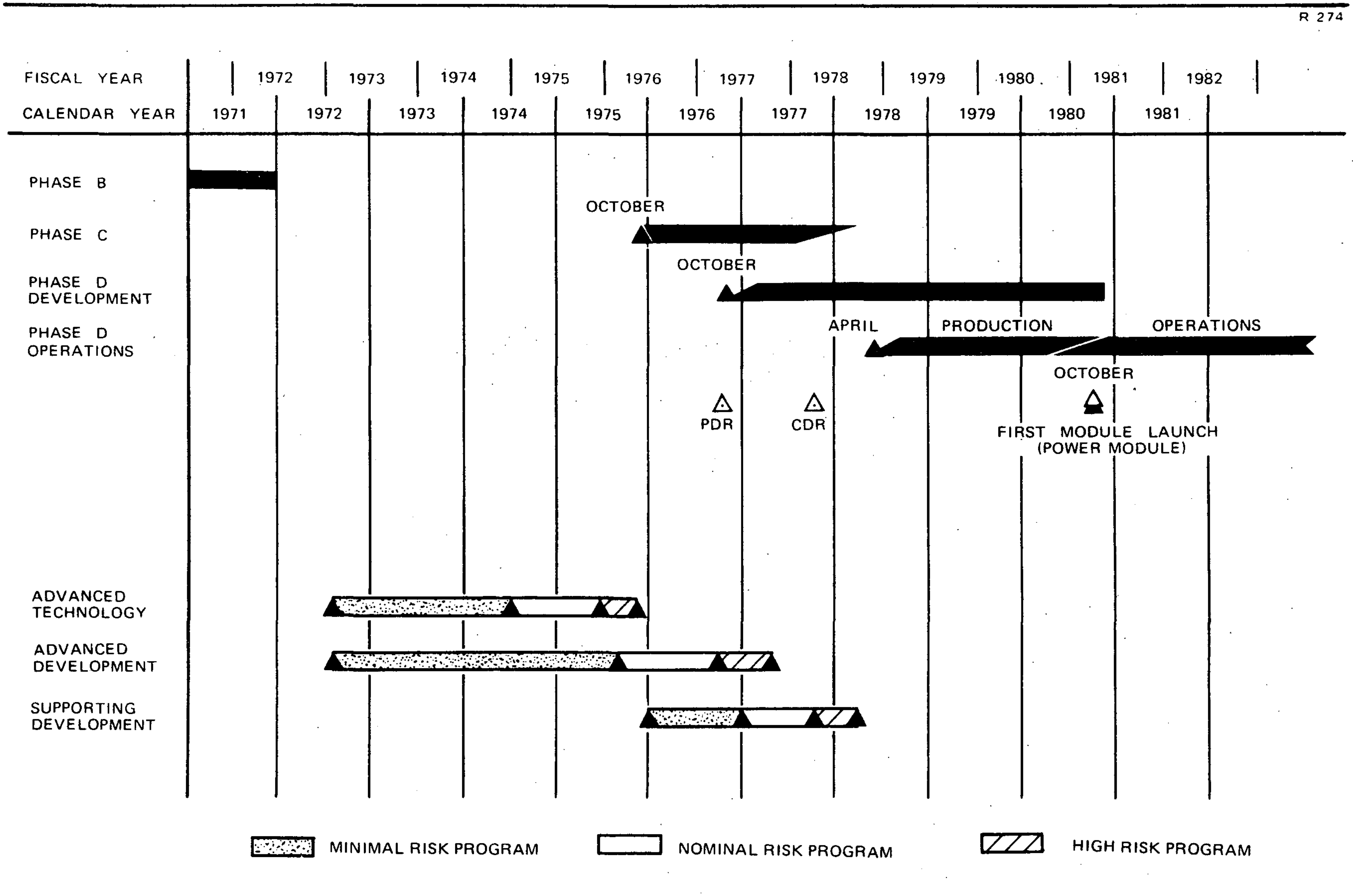

Figure 1-1. Modular Space Station Development/Operations and SRT Interrelationships (ISS Modules - Power, Crew/Operations, and GPL)

The list of 88 SRT items is shown in Table 1-1 and discussed in detail in Section 3. The detailed data for each item include (1) a permanently assigned SRT number, (2) categorization by original NASA technology areas and the Space Station technology panels, (3) a brief discussion of the status of the technology requirement, (4) a brief discussion of the justification for performing the required technology effort, (5) a technical plan which describes the objectives and technical approach for accomplishing the SRT requirements, (6) resource requirements which provides the manpower requirements and funding by fiscal year.

The objective of the SRT was to provide high confidence in the solutions for the various functional system developmental problems, and to do so within a time period compatible with the overall baseline Modular Space Station Program schedule. The SRT appears feasible both from technical and schedule standpoints but is subject to review with respect to funding.

The probability of carrying out the Modular Space Station Program (Phases C and D) in the time phase indicated in Figure 1-1 is predicated on completing the SRT items within the indicated times. If these SRT items are not accomplished, or if they are completed outside their allocated time frames, the probability of achieving the program milestones is very low.

Table 1-1

MODULAR SPACE STATION SRT ITEMS

Category, Number, and Title		Funding Requirements (thousands of dollars)	Page Reference
A. Advance Technology			
M1.	Solar Array Degradation	1,150	24
M2.	Interconnection and Operational Techniques for Multicomputer Systems	400	26
M3.	Magnetic Bubble Storage Techques for Bulk Digital Data	650	28

Table 1-1

MODULAR SPACE STATION SRT ITEMS (Continued)

Category, Number, and Title		Funding Requirements (thousands of dollars)	Page Reference
M4.	Dynamics and Control of Flexible, Multibody Structure	400	30
M5.	Docking Dynamics Procedure and Techniques	300	32
M6.	Navigation Sensor and Software	300	34
M7.	Physical Conditioning in Hypodynamia	230	36
M8.	Man-Machine Interface for Astronomical Instruments	2,250	37
M9.	Contamination Effects on Experiments	2,000	38
B.	Advanced Development		
M10.	Integrated System Development--Solar Arrays, High-Capacity Batteries, and the Modular Space Station	800	43
M11.	Array Orientation/Drive System	700	47
M12.	High-Capacity Battery Evaluation	600	49
M13.	Charge/Discharge Control Technique	800	52
M14.	Random Load Cycling Effects on Batteries	700	54
M15.	Power Management by Computer Techniques	800	56
M16.	Power Regulation System Evaluation	800	59
M17.	Modular Inverter System Development	350	62

Table 1-1

MODULAR SPACE STATION SRT ITEMS (Continued)

Category, Number, and Title		Funding Requirements (thousands of dollars)	Page Reference
M18.	Solid-State Switching for High Voltage and High Current	400	64
M19.	High-Level Power Transfer and Connector Development	700	66
M20.	Optical Image Processor	150	68
M21.	Analog Image Processor	150	69
M22.	Image-Processing Executive Program	30	70
M23.	Computer Simulation of Model of Image-Processing System	100	71
M24.	High-Density Magnetic Recording	400	73
M25.	Multipurpose Displays	300	75
M26.	Integrated Display Techniques	1,150	77
M27.	Laser/Holography Storage Technique for Bulk Data	600	79
M28.	Checkout Parameter Sensing and Associated Calibration Techniques	200	81
M29.	High-Gain Antenna System Maintenance	125	83
M30.	High-Gain Antenna Acquisition and Tracking	100	85
M31.	Advanced Electronic Packaging and Installation Techniques	650	87
M32.	Software Reliability	450	89
M33.	Long-Life Pressure Cabins	1,400	91
M34.	Long-Life Pressure Tanks	750	93
M35.	Dynamic Seals	320	94

Table 1-1

MODULAR SPACE STATION SRT ITEMS (Continued)

Category, Number, and Title		Funding Requirements (thousands of dollars)	Page Reference
M36.	Docking Systems	2,700	95
M37.	Meteor Impact on Biaxially Stressed Materials	600	96
M38.	Adaptive Controller	400	97
M39.	Onboard Sensor Alignment, Calibration, and Maintenance	200	99
M40.	Rendezvous Sensor Improvement	300	101
M41.	Solar-Cell Energy Wheel System	300	103
M42.	Solar-Panel Dynamics	400	105
M43.	Biowaste Resistojet (Engine and System)	1,800	108
M44.	Monopropellant Thrusters (N_2H_4)	1,500	110
M45.	Maintenance, Resupply, Propellant Transfer	1,600	112
M46.	Optical Fine Pointing of Manned Space Experiments	2,000	113
M47.	Waste Collection and Sampling	350	114
M48.	Early Detection of Infectious Disease	325	116
M49.	Environmental Microbiology	230	118
M50.	Body Composition and Fluid Balance Methodology	345	120
M51.	Potable Water Monitoring and Contamination Control	175	121
M52.	Low-Level Environmental Stress	350	123

Table 1-1

MODULAR SPACE STATION SRT ITEMS (Continued)

Category, Number, and Title		Funding Requirements (thousands of dollars)	Page Reference
M53.	Atmosphere Constituent Requirement	50	125
M54.	Decompression Sickness Empirical Model	150	127
M55.	Wash-Water Criteria	150	128
M56.	Biological Specimen Container	2,700	129
M57.	Crew Task Allocation for Data and Experiment Operations	375	130
M58.	Quantification and Measurement of Habitability	350	131
M59.	Accommodations for Female Astronauts	150	133
M60.	EVA Requirements (Manned or Remote)	300	134
M61.	On-Orbit Crew Performance Assessment	375	135
M62.	On-Orbit Maintenance	375	137
M63.	Cargo-Handling, Packing, and Storage	200	138
M64.	Mass Determination Devices	300	139
M65.	Physiologic Monitoring Equipment	13,000	140
M66.	Availability Prediction Method Verification	245	141
M67.	Water System Bacteriological Control and Monitoring	500	143
M68.	Low Partial Pressure CO_2 Removal	1,500	147
M69.	Atmosphere Leak Location	500	149

Table 1-1

MODULAR SPACE STATION SRT ITEMS (Continued)

Category, Number, and Title		Funding Requirements (thousands of dollars)	Page Reference
M70.	Reverse Osmosis for Wash and Condensate Water Recovery	1,000	151
M71.	Solar Collector	725	153
M72.	Radiator and Solar Collector Coating	500	155
M73.	Nonventing Fecal Collector	750	157
M74.	Trace Contaminant Control	450	159
M75.	Orbital Calibration/Active Figure Control Techniques	2,250	161
M76.	Liquid-Handling Apparatus for Bioexperimentation	1,850	162
M77.	Automated Positioning and Retrieval of External Experiments	2,750	163
M78.	On-Orbit Cleaning, Recoating, Servicing, and Calibration of Optical Elements	2,000	164
M79.	Cryogenic Systems for Space Experiments	4,200	165
M80.	General Systems Technology	1,400	166
C.	Supporting Development		
M81.	Ku-Band Low Noise Receiving System	300	169
M82.	Volatile Liquid Pressurization	250	171
M83.	Bellows Expulsion Tankage	700	172
M84.	Bioanalytical Instrumentation	2,250	173
M85.	CO_2 Conversion	700	174

Table 1-1

MODULAR SPACE STATION SRT ITEMS (Continued)

Category, Number, and Title		Funding Requirements (thousands of dollars)	Page Reference
M86.	Water Electrolysis Unit Development	1,200	176
M87.	Photographic Film for Space Experiments	1,850	178
M88.	Film Processor	1,500	179
	Total	82,625	

Section 2
SUPPORTING RESEARCH AND TECHNOLOGY CATEGORIES AND TECHNOLOGY PANELS

During the course of the Modular Space Station Study, specific problem areas requiring supporting research and technology effort were identified. These problem areas have been organized into the NASA SRT categories; i. e., research, advanced technology, advanced development, and supporting development. Within each of these major categories, the problem areas have been further grouped into technology panels. The definitions and descriptions of the types of analysis and equipment included in each category and technology area are presented in the following paragraphs.

2.1 SUPPORTING RESEARCH AND TECHNOLOGY CATEGORIES

2.1.1 Research

Research (R) is the activity directed toward an increase in scientific and engineering knowledge. When the SRT category has a programmatic implication, it is applied rather than basic research and addresses only the conceptual phase (A) of Phased Project Planning.

No Research items were identified because of design guidelines which required minimum cost and maximum use of existing equipment and technology.

2.1.2 Advanced Technology

Advanced technology (AT) is the activity of advancing the state of the art in the field of methods and techniques through the application of science and engineering. Any associated hardware effort does not go beyond that required to demonstrate the validity of the advanced method or technique. The AT category of SRT is primarily concerned with the conceptual phase and has only a secondary concern with the definition Phase (B).

2.1.3 Advanced Development

Advanced development (AD) is the activity of developing systems, subsystems, or components which are recognized as having long development times, prior to Phase D approval of the project in which they will be utilized. The product of the activity is a set of specifications, within the then-current state of the art, which describes the hardware that was the subject of the advanced development activity. The AD category of SRT is concerned with both the definition Phase (B) and the design Phase (C).

2.1.4 Supporting Development

Supporting development (SD) is the activity of developing (1) backup or alternate systems, subsystems, or components, and (2) fabrication, cost, and evaluation techniques. Advances in the state-of-the-art may or may not be incorporated, as appropriate. The products of this activity are hardware or techniques suitable for replacing their primary counterparts in the major development effort being supported. The SD category of SRT is primarily concerned with the design Phase (C).

2.2 SRT TECHNOLOGY PANELS

The Space Station technology panels and their areas of responsibility are as described in subsequent paragraphs.

2.2.1 Power (Electrical) Panel

This category includes the production (source), conversion, conditioning, control and distribution of electrical power. Included are all subsystems and components that pertain to power systems; i.e., solar array, power conversion, etc.

2.2.2 Information Systems Panel

The subsystems and technologies associated with this category are communication, data management, onboard checkout and fault isolation, and controls and displays. Included are all components of these subsystems; i.e., centralized multiprocessors, data bus, multipurpose central and local displays, VHF and S-band, etc.

2.2.3 Materials and Structures Panel

This category includes items pertaining to materials technology, including chemical analysis, the mechanical design/hardware associated with the station, and manufacturing and assembly techniques. Included in the areas are basic structure, docking system, pressure shells, tankage, seals, radiators, meteoroid shield, welding techniques, radiation effects and shielding, thermal control features of the structure, external contamination, etc.

2.2.4 Control Panel

The subsystems and techniques associated with this category are stabilization and attitude control, guidance and navigation, propulsion (reaction control), dynamics and flight mechanics.

2.2.5 Bioresearch Panel

This category pertains to scientific investigation and equipment used to advance the technology in the areas of space medicine, hygiene and health. This includes experimental equipment and techniques to assess man's capability to function normally in space for long periods of time, and instrumentation to assess the effects of the space environment on man and man's capabilities to perform work in space. Biology is also included in this category.

2.2.6 Bioengineering Panel

The areas of interest for this category are man-machine integration, habitability, teleoperators, bioinstrumentation, and maintainability.

2.2.7 Bioenvironmental Panel

This category includes items pertaining to food, water, and waste management; atmosphere generation storage and control and contaminant monitoring and control; atmosphere purification; integrated life support systems and protective systems, including thermal control equipment; and measurement and instrumentation. Also included in the category is crew equipment/systems.

2.2.8 Experiment Integration

This technology area covers the equipment development, activities, procedures, and techniques required to perform the integration of the experiments into the Modular Space Station. The area is system- rather than subsystem-level-oriented and requires the knowledge of the Space Station configurational design and operations.

2.2.9 Management Techniques

This technology area covers the development of procedures, techniques, methodologies, etc., required to effectively manage the Modular Space Station project.

The first seven areas are commensurate with the present Space Station technology panels, and the eight and ninth are new technology areas created by MDAC to cover various areas that do not fit the technology panels, as presently defined.

Table 2-1 shows the SRT items categorized by these panels for the convenience of those associated with these panels. It should be noted that all items have been assigned a permanent SRT number. The numbers 1 through 500 were assigned to the Space Station Program (see DRL-160, Line Item 18, Volume IV). Thus, the Modular Space Station will utilize these numbers but will be preceded with the letter "M" to distinguish between the two studies.

Table 2-1

SRT BY TECHNOLOGY PANELS (Page 1 of 5)

Power Panel

M1.	Solar Array Degradation
M10.	Integrated System Development - Solar Arrays, High-Capacity Batteries, and the Modular Space Station
M11.	Array Orientation/Drive System
M12.	High-Capacity Battery Evaluation
M13.	Charge/Discharge Control Technique

Table 2-1

SRT BY TECHNOLOGY PANELS (Page 2 of 5)

M14.	Random Load Cycling Effects on Batteries
M15.	Power Management by Computer Techniques
M16.	Power Regulation System Evaluation
M17.	Modular Inverter System Development
M18.	Solid-State Switching for High Voltage and High Current
M19.	High-Level Power Transfer and Connector Development
Information System Panel	
M2.	Interconnection and Operational Techniques for Multicomputer Systems
M3.	Magnetic Bubble Storage Techniques for Bulk Digital Data
M20.	Optical Image Processor
M21.	Analog Image Processor
M22.	Image Processing Executive Program
M23.	Computer Simulation of Model of Image Processing System
M24.	High-Density Magnetic Recording
M25.	Multipurpose Displays
M26.	Integrated Display Techniques
M27.	Laser/Holography Storage Technique for Bulk Data
M28.	Checkout Parameter Sensing and Associated Calibration Techniques
M29.	High-Gain Antenna System Maintenance
M30.	High-Gain Antenna Acquisition and Tracking
M31.	Advanced Electronic Packaging and Installation Techniques
M32.	Software Reliability
M81.	Ku-Band Low Noise Receiving System

Table 2-1

SRT BY TECHNOLOGY PANELS (Page 3 of 5)

Materials and Structures Panel	
M33.	Long-Life Pressure Cabins
M34.	Long-Life Pressure Tanks
M35.	Dynamic Seals
M36.	Docking Systems
M37.	Meteor Impact on Biaxially Stressed Materials
Control Panel	
M4.	Dynamics and Control of Flexible, Multibody Structure
M5.	Docking Dynamics Procedure and Techniques
M6.	Navigation Sensor and Software
M38.	Adaptive Controller
M39.	Onboard Sensor Alignment, Calibration, and Maintenance
M40.	Rendezvous Sensor Improvement
M41.	Solar-Cell Energy Wheel System
M42.	Solar-Panel Dynamics
M43.	Biowaste Resistojet (Engine and System)
M44.	Monopropellant Thrusters (N_2H_4)
M45.	Maintenance, Resupply, Propellant Transfer
M46.	Optical Fine Pointing of Manned Space Experiments
M82.	Volatile Liquid Pressurization
M83.	Bellows Expulsion Tankage
Bioresearch Panel	
M7.	Physical Conditioning in Hypodynamia
M47.	Waste Collection and Sampling
M48.	Early Detection of Infectious Disease

Table 2-1

SRT BY TECHNOLOGY PANELS (Page 4 of 5)

M49.	Environment Microbiology
M50.	Body Composition and Fluid Balance Methodology
M51.	Potable Water Monitoring and Contamination Control
M52.	Low-Level Environmental Stress
M53.	Atmosphere Constituent Requirement
M54.	Decompression Sickness Empirical Model
M55.	Wash-Water Criteria
M56.	Biological Specimen Container
Bioengineering Panel	
M8.	Man-Machine Interface for Astronomical Instruments
M57.	Crew Task Allocation for Data and Experiment Operations
M58.	Quantification and Measurement of Habitability
M59.	Accommodations for Female Astronauts
M60.	EVA Requirements (Manned or Remote)
M61.	On-Orbit Crew Performance Assessment
M62.	On-Orbit Maintenance
M63.	Cargo-Handling, Packing, and Storage
M64.	Mass-Determination Devices
M65.	Physiologic Monitoring Equipment
M66.	Availability Prediction Method Verification
M84.	Bioanalytical Instrumentation
Bioenvironmental Panel	
M67.	Water System Bacteriological Control and Monitoring
M68.	Low Partial Pressure CO_2 Removal
M69.	Atmosphere Leak Location

Table 2-1

SRT BY TECHNOLOGY PANELS (Page 5 of 5)

	M70.	Reverse Osmosis for Wash and Condensate Water Recovery
	M71.	Solar Collector
	M72.	Radiator and Solar Collector Coating
	M73.	Nonventing Fecal Collector
	M74.	Trace Contaminant Control
	M85.	CO_2 Conversion
	M86.	Water Electrolysis Unit Development
Experiment Integration		
	M9.	Contamination Effects on Experiments
	M75.	Orbital Calibration/Active Figure Control Techniques
	M76.	Liquid-Handling Apparatus for Bioexperimentation
	M77.	Automated Positioning and Retrieval of External Experiments
	M78.	On-Orbit Cleaning, Recoating, Servicing, and Calibration of Optical Elements
	M79.	Cryogenic Systems for Space Experiments
	M87.	Photographic Film for Space Experiments
	M88.	Film Processor
Management Techniques		
	M80.	General Systems Technology

Section 3
SUPPORTING RESEARCH AND TECHNOLOGY ITEMS

The SRT items have been identified for the Modular Space Station Project of the Modular Space Station Program. The project, its breakdown, and relationship to the other elements of the program are shown in Figure 3-1. The SRT for this project has been categorized into advanced technology, advanced development, and supporting development. Included within these categories are the SRT requirements for the integration of the experiments into the General Purpose Laboratory Module.

Detailed data for each of the SRT items are presented in the following pages. Each item includes (1) a permanently assigned SRT number, (2) categorization by original NASA technology areas and the Space Station technology panels, (3) a brief discussion of the status of the technology requirement, (4) a brief discussion of the justification for performing the required technology effort, (5) a technical plan which describes the objectives and technical approach for accomplishing the SRT requirement, and (6) resources requirements, which provides the manpower requirements and funding by fiscal year. The funding is for the SRT described in the detailed data sheets. Costs to perform SRT associated with other categories are not included. As an example, if the SRT item is in the advanced-technology category and additional SRT effort will be required in advanced development at a later date, the cost for this work has not been included.

It is assumed that all SRT tasks within this document could not start until fiscal 1973. However, it is recognized that various SRT are being investigated and could be used to support the activities described herein. Thus, where applicable, these activities have been so noted in the descriptive material for that SRT item.

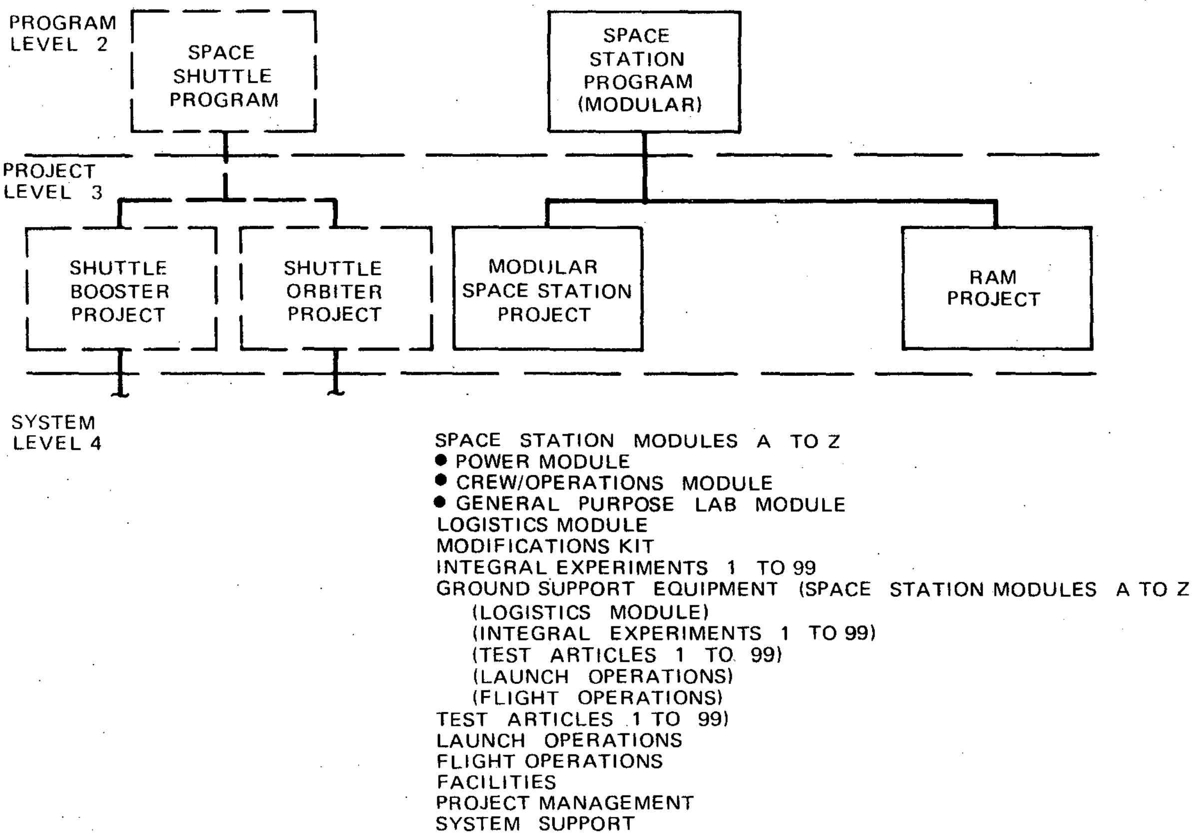

Figure 3-1. Work Breakdown Structure for Space Station Program (Modular)

3.1 ADVANCED TECHNOLOGY

This category of activities requires the initiation of scientific and engineering analysis and/or testing to advance the state-of-the-art in methods and techniques. These activities should be completed prior to the start of Phase C, if program risk is to be minimized. The hardware activities associated with advanced technology objectives should not extend beyond those required to demonstrate validity. The SRT items identified for this category are summarized in Table 3-1. Detailed data follow for each of the items.

Table 3-1

ADVANCE TECHNOLOGY SRT ITEMS

SRT Category, Number, and Title		Technology Panel
M1.	Solar Array Degradation	P
M2.	Interconnection and Operational Techniques for Multicomputer Systems	IS
M3.	Magnetic Bubble Storage Techniques for Bulk Digital Data	IS
M4.	Dynamics and Control of Flexible, Multibody Structure	C
M5.	Docking Dynamics Procedure and Techniques	C
M6.	Navigation Sensor and Software	C
M7.	Physical Conditioning in Hypodynamia	B-RES
M8.	Man-Machine Interface for Astronomical Instruments	B-ENG
M9.	Contamination Effects on Experiments	EI

Legend:

P - Power
IS - Information Systems
C - Control
B-RES - Bioresearch
B-ENG - Bioengineering
EI - Experiment Integration

SRT M1

1. Item: Solar Array Degradation

2. Category: Advanced Technology

3. Technology Area/Panel: Power

4. Status:

Basic substrate materials have been under study for an extended period of time. The current NASA/MSC Contract NAS9-11039 with Lockheed Missile and Space Company (LMSC) includes tasks to examine tear characteristics, tensile strength, and substrate creep characteristics for a number of materials at temperatures up to 160°F, but this work does not provide for sufficiently long-term effects nor for combined environmental effects.

5. Justification:

While the work accomplished or proposed to date is fairly comprehensive in the scope of the materials and environments considered, it requires much longer duration testing to provide significant new knowledge pertinent to 10-year or longer life applications. Further, an appropriate combination of environments and materials will be needed to select and qualify materials. For example, long-term storage "memory" effects, thermal cycling combined with vacuum outgassing effects on material creep characteristics, flexibility and brittleness, shock or impact loading effects on tear resistance, retraction/deployment stresses after long-term exposure to space environment, tolerance to ultraviolet or gamma radiation, contaminants, micrometeorites, and long-duration vibration modes of cell covers, adhesives, thermal coatings, and electrical or thermal insulation materials. Lubricants, motor insulation, power cable insulation, dielectric materials under high electrical stress, and electric brush materials (if used) require verification over long periods of use under the actual environments they will experience.

6. Technical Plan:

A. Objectives

The principal objectives of this program are to determine material tolerances to single and multiple adverse environmental factors, to determine their characteristics after long-term exposure to the total space environment, to verify their adequacy to provide for a 5- to 10-year or longer mission, and to determine and verify means of either controlling the degradation or limiting the exposure in order to extend the acceptable mission lifetime. Thermal control material will receive a substantial effort, as will thin-film, dielectric, multilayer cover filters for solar cells.

B. Technical Approach

1. Develop the required test parameters and conditions -- structural, mechanical, illumination, irradiation, electrical, vacuum, and temperatures -- with change rates and ranges.
2. Develop a test program to provide the meaningful combinations of simultaneous environmental conditions to which the materials may be exposed. Establish test durations, number of test samples and control samples, and the single-test samples in order to generate reference data for the combined test results. Establish time durations, stress levels, and ranges.
3. Perform the tests and evaluate alternative materials.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975	Advance Development FY 1976
Manpower (Man-yr)	4	4	4	4
Funding				
Engineering	$200,000	$200,000	$200,000	$200,000
Equipment and Materials	50,000	100,000	100,000	100,000
Total	$250,000	$300,000	$300,000	$300,000

1. Item: Interconnection and Operational Techniques for Multicomputer Systems

2. Category: Advanced Technology

3. Technology Area/Panel: Information Systems

4. Status:

Technology will largely dictate operational characteristics including circuit logic integration levels, compatible memory hierarchy (on an access-time basis), and associated system requirements such as data bus bandwidth, thermal control, etc. Technology forecasts for 1972-1974 include 200 to 500 circuits/chip, 2 to 6 msec transistor-transistor-logic (TTL) circuits, 2 watts/1,000 circuits, 0.5- to 1.0-microsec memory cycle times, and 200- to 500-cu in. volume computer units (including CPV and memory).

5. Justification:

Air in definition of more efficient and improved performance computer-system configuration.

6. Technical Plan:

A. Objectives

To properly satisfy the requirements for performing varied computational tasks and meeting required reliability/availability goals, studies in the area of computer unit interconnection techniques and operational policies need to be examined and evaluated. This includes centralized versus federated systems, as well as lower-level interconnection methods.

B. Technical Approach

1. Examination of main module interconnection techniques. (In addition to data bus, cross-bar switching, and multiport configurations, hybrid techniques will be considered.)
2. Definition of the relationship between technology parameters and machine performance and reliability for various interconnection methods.

3. Determination of the preferred ratios of module-type quantities as a function of module size-performance capability.
4. Assessment of the relative software requirements for each parallel processor organization.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (Man Yrs)	5	3
Funding		
Engineering	$250, 000	$150, 000
Equipment and Materials	0	0
Total	$250, 000	$150, 000

SRT M3

1. Item: Magnetic-Bubble Storage Techniques for Bulk Digital Data*

2. Category: Advanced Technology

3. Technology Area/Panel: Information Systems

4. Status:

Bell Laboratories has demonstrated the basic technology for digital data storage by formation of magnetic bubbles in orthoferrites. Although holography ultimately promises the highest density potential, magnetic-bubble technology promises to make possible low-cost, high-capacity storage in an earlier time frame. A feasibility study is now underway to include defining a development program using this technique for storage of large quantities of digital data.

5. Justification:

Development work is needed as a follow-on to the feasibility study to bring this new technology up to its full potential. The primary benefit from using this technology over existing ones is the larger storage density potential. It also promises lower cost per bit and lower power consumption than any other approach available today or projected for the Modular Space Station time period.

6. Technical Plan:

A. Objectives

Development of magnetic-bubble storage device for storage of large quantities of digital data. The full potential of this technology is expected to yield digital data storage devices with the following capabilities:

1.	Bit density	10^8 bits/sq in.
2.	Recording rate	3×10^6 bits/sec
3.	Access rate	100 microseconds
4.	Power	0.04 watt/10^{12} binary operations
5.	Cost	0.001 cent/bit

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*Recommended for Growth Space Station Application

B. Technical Approach

Development of magnetic-bubble storage devices for bulk digital data will use the basic technology developed by Bell Laboratories and the results of the current feasibility study for this type of application. The basic technology accomplishes digital data storage by formation of cylindrical magnetic domains (magnetic bubbles) in single-crystal magnetic oxides called orthoferrites. Domain diameters range from 10^{-3} to 10^{-5} in. in orthoferrites, resulting in a theoretical maximum storage density of 10^5 bits/sq-in. in orthoferrites and up to 10^8 bits/sq-in. in other materials. The domains can be formed and moved under appropriate magnetic and dimensional conditions. They will remain stable over a range of bias yield values. The specific technical problems to be resolved will be identified in the feasibility study results.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	3	3	4
Funding			
Engineering	$150,000	$150,000	$200,000
Equipment and Materials	0	50,000	100,000
Total	$150,000	$200,000	$300,000

SRT M4

1. Item: Dynamics and Control of Flexible, Multibody Structure

2. Category: Advanced Technology

3. Technology Area/Panel: Control

4. Status:

Current capability for control system analyses of flexible, multibody structure are practically nonexistent.

5. Justification:

Dynamic analyses of modular constructed stations are very complex and at best only approximations to the real hardware behavior. Past and present programs depended on dynamic testing as a final check of vehicle dynamic behavior, even when thorough analyses were conducted.

However, the design of vehicle structure and control system and verification of their adequacy must be established early in a program when no test data are available, and therefore a good analytical technique is required early in the Modular Space Station Program.

The NASTRAN program can be utilized to generate these flexible modes for the uncontrolled dynamic case. A separate program is required for the dynamic case with the attitude controller and disturbance effects.

6. Technical Plan:

A. Objectives

Provide control system designer with an analysis and simulation tool for defining the flexible-body dynamic interaction with the control system.

B. Technical Approach

Define the model of the flexible Modular Station and include the dynamic of the major latching interface mechanisms.

Determine the vehicle structural dynamics by use of the NASTRAN program of the Station model.

Develop a computer program for the controlled, flexible-body dynamics model and provide for external disturbance effects. (The output of the NASTRAN program will be modeled and user as parameter input to this program.)

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	4	4
Funding		
Engineering	$200,000	$200,000
Equipment and Manuals	0	0
Total	$200,000	200,000

1. Item: Docking Dynamics Procedures and Techniques

2. Category: Advanced Technology

3. Technology Area/Panel: Control

4. Status:

The docking procedure and technique may be dependent on the dynamic conditions as well as the configuration. Current operational docking procedures may have to be altered or changed to be compatible with the specific docking-latch mechanism and docking configuration. Existing docking models and studies (SKYLAB) would be utilized to the fullest extent.

5. Justification:

Simulation of the procedures and techniques will provide the necessary design data for the flight control systems, the docking equipment, and operational procedures. The docking dynamics are complex, and the analysis is at best an approximation to the real hardware characteristics. This simulation will provide essential concept verification data for the frame and latch-mechanism designs.

6. Technical Plan:

A. Objectives

Develop dynamic analysis to define the docking loads and operation of the docking-latch mechanism. Define the operational modes for the reaction control system (RCS) in order to insure a positive latching operation for the expected docking dynamic conditions. Simulation will be conducted to insure proper latching operations for the docking condition.

B. Technical Approach

1. Formulate the docking dynamics with the candidate latching mechanisms.
2. Define the RCS control logic schemes for the docking operations.
3. Define a range of docking conditions for the simulation.
4. Establish space vehicle range of physical characteristics.
5. Perform simulation for the candidate latching mechanism and RCS with the defined docking conditions.
6. Develop preliminary latching mechanism design and RCS operation requirements.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	4	2
Funding		
Engineering	$200,000	$100,000
Equipment and Materials	0	0
Total	$200,000	$100,000

SRT M6

1. Item: Navigation Sensor and Software

2. Category: Advanced Technology

3. Technology Area/Panel: Control

4. Status:

Considerable work has been accomplished in this area for landmark tracking, star trackers, and gyros working in conjunction with each other under research and development contracts.

5. Justification:

The software required for overall autonomous orbital navigation is not defined for a system with minimum external sensors. Concepts utilizing the onboard attitude reference sensors such as the horizon sensor, star trackers, and gyros and satellite ranging should be investigated. This would eliminate the need for an additional special sensor; i.e., landmark tracker.

6. Technical Plan:

A. Objectives

Define an autonomous navigation system using the complement of attitude reference sensors (horizon sensor, star tracker, gyros) and the necessary software.

B. Technical Approach

1. Establish candidate autonomous navigation concepts using the overall sensor complement of horizon sensor, star trackers, gyros, landmark tracker, and satellite ranging.
2. Define the filtering techniques required for these concepts and investigate initializing techniques.
3. Determine the performance of the selected concept or concepts, and develop the necessary software for autonomous navigation.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	4	2
Funding		
Engineering	$200,000	$100,000
Equipment and Materials	0	0
Total	$200,000	$100,000

SRT M7

1. Item: Physical Conditioning in Hypodynamia

2. Category: Advance Technology

3. Technical Area/Panel: Bioresearch

4. Status:

Current fitness programs are directed primarily against specific problems and do not combine countermeasures to alleviate combined effects of hypodynamic conditions.

5. Justification:

Deconditioning in weightlessness and bed-rest studies include cardiovascular decompensation, muscular weakening and atrophy, bone demineralization, and loss of body fluids. Efforts to define countermeasures for these effects have been directed toward specific deconditioning factors rather than toward a total program for the maintenance of physical conditioning.

6. Technical Plan:

A. Objectives

Define a single fitness program which minimizes crewtime expenditure and equipment development costs.

B. Technical Approach

1. Develop methods for rapidly and accurately assessing all aspects of physical conditioning.
2. Test various programs of combined exercises.
3. Define single programs for the maintenance of overall physical conditioning in hypodynamics.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2	2
Funding:		
Engineering	$100,000	$100,000
Equipment and Materials	10,000	20,000
Total	$110,000	$120,000

SRT M8

1. Item: Man-Machine Interface for Astronomical Instruments

2. Category: Advanced Technology

3. Technology Area/Panel: Bioengineering

4. Status:

Very little work has been done on how man interfaces with sophisticated astronomy instruments.

5. Justification:

Studies must be undertaken to determine what functions are best performed by the onboard crew member, what can be done under automated computer control, and what will be performed by a principal investigator team at a ground-based control center. In addition, the interface of man for calibration, adjustment, and analysis of data must be studied.

6. Technical Plan:

The tasks associated with this item are to determine what instrument control functions, calibration operations, and instrument checkout are best performed by an astronaut astronomer.

Simulation of orbital astronomy instruments and operation of real ground-based instruments can determine the best approaches to the man-machine interface.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975	Advanced Development FY 1976
Manpower (man-yr)	4	4	4	4
Funding				
Engineering	$200,000	$200,000	$200,000	$200,000
Equipment and Materials	50,000	300,000	550,000	550,000
Total	$250,000	$500,000	$750,000	$750,000

SRT M9

1. Item: Contamination Effects on Experiments
2. Category: Advanced Technology
3. Technology Area/Panel: Experiment Integration
4. Status

Some work has been done in this area, but very little data useful for experiment or space station design have been generated.

5. Justification

A program of research and testing to determine sources of contamination must be conducted concurrently with the advanced development of contaminant sensors in order to support the measurement programs on Skylab and the Modular Space Station. The Space Station experiments must be reexamined in light of these data, and appropriate protective techniques must be applied.

6. Technical Plan:

The tasks associated with this item are to analyze sources of contamination on experiments, to analyze and test the effects of contamination on experiments, and to propose solutions to the problem if one exists.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	6	10
Funding			
Engineering	$100,000	$300,000	$500,000
Equipment and Materials	150,000	450,000	500,000
Total	$250,000	$750,000	$1,000,000

3.2 ADVANCED DEVELOPMENT

Subsystems and components listed in this category are those which are felt to require long development lead times. These activities normally start during the definition Phase (B), but in selected cases they may begin some months prior to this time and extend into the design Phase (C). The primary reason for performing this type of SRT is to definitize the performance requirement portions of the specification associated with the hardware.

For the problem areas discussed in this category, the technology is present and broad feasibility has been shown, but there remains the long-term tasks of (1) integrating the elements into a workable subsystem and (2) demonstrating operational capability in the space environment. The Modular Space Station itself could be the final test bed for a number of these concepts.

The SRT items identified for this category are summarized in Table 3-2. Detailed data follow for each item.

Table 3-2. (Page 1 of 4)
ADVANCED DEVELOPMENT SRT ITEMS

SRT Category, Number, and Title	Technology Panel
M10. Integrated System Development - Solar Arrays, High-Capacity Batteries, and the Modular Space Station	P
M11. Array Orientation/Drive System	P
M12. High-Capacity Battery Evaluation	P
M13. Charge/Discharge Control Technique	P
M14. Random Load Cycling Effects on Batteries	P
M15. Power Management by Computer Techniques	P
M16. Power Regulation System Evaluation	P
M17. Modular Inverter System Development	P
M18. Solid-State Switching for High Voltage and High Current	P
M19. High-Level Power Transfer and Connector Development	P
M20. Optical Image Processor	IS
M21. Analog Image Processor	IS

Table 3-2. (Page 2 of 4)

ADVANCED DEVELOPMENT SRT ITEMS (Continued)

SRT Category, Number, and Title	Technology Panel
M22. Image Processing Executive Program	IS
M23. Computer Simulation of Model of Image-Processing System	IS
M24. High-Density Magnetic Recording	IS
M25. Multipurpose Displays	IS
M26. Integrated Display Techniques	IS
M27. Laser/Holography Storage Technique for Bulk Data	IS
M28. Checkout Parameter Sensing and Associated Calibration Techniques	IS
M29. High-Gain Antenna System Maintenance	IS
M30. High-Gain Antenna Acquisition and Tracking	IS
M31. Advanced Electronic Packaging and Installation Techniques	IS
M32. Software Reliability	IS
M33. Long-Life Pressure Cabins	MS
M34. Long Life Pressure Tanks	MS
M35. Dynamic Seals	MS
M36. Docking Systems	MS
M37. Meteor Impact on Biaxially Stressed Materials	MS
M38. Adaptive Controller	C
M39. Onboard Sensor Alignment, Calibration, and Maintenance	C
M40. Rendezvous Sensor Improvement	C
M41. Solar-Cell Energy Wheel System	C
M42. Solar Panel Dynamics	C
M43. Biowaste Resistojet (Engine and System)	C
M44. Monopropellant Thrusters (N_2H_4)	C
M45. Maintenance, Resupply, Propellant Transfer	C
M46. Optical Fine Pointing of Manned Space Experiments	C
M47. Waste Collection and Sampling	B-Res
M48. Early Detection of Infectious Disease	B-Res

Table 3-2. (Page 3 of 4)

ADVANCED DEVELOPMENT SRT ITEMS (Continued)

SRT Category, Number, and Title	Technology Panel
M49. Environmental Microbiology	B-Res
M50. Body Composition and Fluid Balance Methodology	B-Res
M51. Potable Water Monitoring and Contamination Control	B-Res
M52. Low-Level Environmental Stress Criteria	B-Res
M53. Atmosphere Constituent Requirement	B-Res
M54. Decompression Sickness Empirical Model	B-Res
M55. Wash-Water Criteria	B-Res
M56. Biological Specimen Container	B-Res
M57. Crew Task Allocation for Data and Experiment Operations	B-Eng
M58. Quantification and Measurement of Habitability	B-Eng
M59. Accommodations for Female Astronauts	B-Eng
M60. EVA Requirements (Manned or Remote)	B-Eng
M61. On-Orbit Crew Performance Assessment	B-Eng
M62. On-Orbit Maintenance	B-Eng
M63. Cargo Handling, Packing, and Storage	B-Eng
M64. Mass Determination Devices	B-Eng
M65. Physiologic Monitoring Equipment	B-Eng
M66. Availability Prediction Method Verification	B-Eng
M67. Water-System Bacteriological Control and Monitoring	B-Env
M68. Low Partial Pressure CO_2 Removal	B-Env
M69. Atmosphere Leak Location	B-Env
M70. Reverse Osmosis for Wash and Condensate Water Recovery	B-Env
M71. Solar Collector	B-Env
M72. Radiator and Solar Collector Coating	B-Env
M73. Nonventing Fecal Collector	B-Env
M74. Trace Contaminant Control	B-Env
M75. Orbital Calibration/Active Figure Control Techniques	EI

Table 3-2. (Page 4 of 4)
ADVANCED DEVELOPMENT SRT ITEMS (Continued)

SRT Category, Number, and Title	Technology Panel
M76. Liquid-Handling Apparatus for Bioexperimentation	EI
M77. Automated Positioning and Retrieval of External Experiments	EI
M78. On-Orbit Cleaning, Recoating, Servicing, and Calibration of Optical Elements	EI
M79. Cryogenic Systems for Space Experiments	EI
M80. General Systems Technology	MT

Legend:

P - Power
IS - Information System
M&S - Materials and Structure
C - Control
B-RES - Bioresearch
B-Eng - Bioengineering
B-Env - Bioenvironment
EI - Experiment Integration
MT - Management Techniques

SRT M10

1. Item: Integrated System Development - Solar Arrays, High-Capacity Batteries, and the Modular Space Station

2. Category: Advanced Development

3. Technology Area/Panel: Power

4. **Status:**

The current NASA/MSC Contract NAS9-11039 with Lockheed Missile and Space Company (LMSC) provides for development of a 10,000 sq ft solar array with limited (partial-deployment) artificial-g capability and for the fabrication and test of a 2,500-sq-ft quadrant of the array. This work is programmed for completion in January 1972.

The current NASA/MSC Contract NAS9-11074 with Grumman Aerospace Corporation (GAC) provides for development of a 100-amp-hr battery with optimization of fabrication techniques and materials, develops and utilizes strict quality control techniques, and provides for extensive testing of alternatives at each stage of development. The final product, a 100-amp-hr, 28-v battery, will be available in 1972, prior to extended life testing.

Another program for development of 100-amp-hr cells is in progress at Gulton Industries on contract to NASA/Langley Research Center. The batteries are of the balanced-geometry, opposed-terminal design. At present, the test cells are temporarily recalled from testing, pending verification of carbonate reduction techniques, after which life-cycling tests will be continued at the NAD-Crane, Indiana laboratories. The final report is due in November 1971.

Recent NASA/Langley Research Center contracts with Heliotech for 200-amp-hr cells and for high-quality cell plaques are commencing and will be completed in 1973.

The data from both the LMSC solar array and the GAC battery test programs will be available in CY 1972 and 1973. The NASA/Langley Research Center contract data on balanced-geometry 100-amp-hr cells are available now, and 200-amp-hr cell data are proposed for FY 1972.

5. Justification:

No work is presently programmed to perform the integration study necessary to combine the Lockheed flexible solar array, the Grumman 100-amp-hr battery (or an alternative design), and the MDAC Modular Space Station. The array sizing, control, and regulation functions; the orientation/drive requirements, the battery modularization, the charge/discharge control functions, instrumentation, and the display/control requirements -- all must be related to the Modular Space Station load analysis, power quality, and load profile characteristics in order to produce an integrated 24-hr power source. This work can be properly performed only by the Space Station prime contractor with full regard for operational, configurational, and developmental requirements.

6. Technical Plan

A. Objectives:

The objectives of the program will be to provide a technically integrated and optimally sized assembly of solar-array power source, NiCd battery energy storage, battery chargers, line regulators, instrumentation, and necessary peripheral equipment to meet the specifications and requirements defined for the MDAC Modular Space Station design. The integration should be verified by operation of interfacing elements on the concept verification test (CVT) program.

B. Technical Approach:

1. Review Lockheed Missile and Space Company (LMSC) solar array test and analytical data with respect to the MDAC Modular Space Station source requirements.
2. Extrapolate LMSC data to characterize the solar array for the Modular Space Station size.
3. Verify the solar array, Space Station, and attitude control dynamics compatibility (SRT item, Solar Array Dynamics) for methodology.
4. Review the materials for environmental compatibility, introduce environmental protection/control methods, and evaluate associated penalties (SRT item, Environmental Tolerance and Environmental Control Techniques).

5. Review the Grumman Aerospace Corporation 100-amp-hr NiCd battery and/or cell data with respect to the MDAC Modular Space Station electrical load and orbital parameters. Also project these data to full 120-v battery string requirements, size the battery set required for one string, and establish the switching/control techniques for matching batteries to loads and to solar panels (or strips).
6. Review the Gulton Industries and Heliotech NiCd battery data by comparison with the Grumman Aerospace Corporation (GAC) battery studied in Task 5. Note that the work accomplished on a related SRT item -- High Capacity Battery Evaluation -- should be useful for this task.
7. Establish the charging, charge control, instrumentation, and line regulation requirements, and develop these into prototype hardware.
8. Breadboard essential alternatives for comparative testing, using a standard load profile to simulate a Modular Space Station load profile.
9. Test the hardware items in groups sufficiently large to represent an identifiable building block or integral part of the Modular Space Station system. This may then be incorporated into the CVT program for single-module testing and interface study.
10. Combine two (or more) such groups as are tested in Task 9 above, in order to demonstrate and verify the stability, performance, and interface compatibility of the modular groups that comprise the full Modular Space Station electrical power system (EPS).
11. Iterate Tasks 7 to 10 as necessary to optimize the overall electrical power system (EPS) and to improve the integrated system characteristics.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	3	3	3
Funding			
Engineering	$150,000	$150,000	$150,000
Equipment and Materials	50,000	150,000	150,000
Total	$200,000	$300,000	$300,000

SRT M11

1. Item: Array Orientation/Drive System

2. Category: Advanced Development

3. Technology Area/Panel: Power

4. Status:

An orientation/drive system concept is now in development, under Contract NAS9-11039 from NASA/MSC to Lockheed Missile and Space Company and subcontracted to Ball Brothers Research Corporation. This design is tailored to the NAR Space Station concept and cannot effectively be reconfigured for the MDAC Space Station. The MDAC orientation/drive system concept has been designed to the Phase B level, but no physical development work has been conducted. Because each design is unique to the parent Space Station -- although common fixtures may be used -- the status of one program has little effect on the other. However, lubricant, bearing, drive-motor, and some other mechanical developments can be utilized for all designs.

5. Justification:

Each new Space Station configuration poses a unique design/configuration requirement for the solar-array orientation and drive system, even though principal features may be similar. The Ball Brothers Research Corporation (BBRC) design for Lockheed on the NASA-MSC Contract NAS9-11039 provides for a design and development of an orientation and drive system which is unique to the NAR Space Station design requirements. An evaluation shows the design to be incompatible with MDAC Space Station design requirements. In particular, the MDAC requirements for (1) shirt-sleeve access to the drive turret during operation and maintenance, (2) replaceability of all wear-sensitive components (bearings, dynamic seals, motors, etc.) in a shirt-sleeve environment, (3) flexible cable rather than slip-ring power transfer, and (4) flexible hoses for solar heating fluid transfer, are among those which the BBRC design does not meet. These are design features which involve technology advancement as well as conventional engineering development and are necessary for demonstration before commitment of the Space Station to a particular design.

6. Technical Plan:

A. Objectives:

The objectives of this program will be to provide a full-scale solar array orientation and drive system and to test it in the simulated conditions of space vacuum and temperatures with orbital temperature changes and normal loads. Sufficient test time should be provided to verify the replacement requirements for a 10-year or longer program, and the replacement capability in shirt-sleeve internal environment should be demonstrated.

B. Technical Approach

1. Complete the orientation/drive system design.
2. Fabricate the orientation/drive system, turret, and tunnel end.
3. Install the turret in a vacuum enclosure capable of simulating space temperatures and vacuums. Access to the turret interior should be exposed to normal atmosphere, but should also be capable of sealing off to allow simulated loss of pressure in the turret housing.
4. Develop the test program and plan.
5. Perform the long-term and operational tests, and evaluate the design.
6. Redesign and retest as necessary.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yrs)	1	1	2	1
Funding				
Engineering	$ 50,000	$ 50,000	$100,000	$ 50,000
Equipment and Materials	100,000	100,000	150,000	100,000
Total	$150,000	$150,000	$250,000	$150,000

SRT M12

1. Item: High-Capacity Battery Evaluation

2. Category: Advanced Development

3. Technology Area/Panel: Power

4. Status:

The current NASA/MSC Contract NAS9-11074 with Grumman Aerospace Corporation (GAC) provides for development of a 100-ampere-hour (AHr) battery with optimization of fabrication techniques and materials, develops and utilizes strict quality control methods, and provides for extensive testing of alternatives at each stage of development. The final product is a 100-AHr, 28-volt battery, which will be available in 1972 prior to the extended-life testing. Cell fabrication is presently being done by Eagle-Picher.

Another program for development of 100-AHr cells is in progress at Gulton Industries on contract to NASA/Langley Research Center. The batteries are of the balanced-geometry, opposed-terminal design. At present, the test cells are temporarily withdrawn from the testing program at the NAD-Crane (Indiana) laboratories, pending verification of carbonate reduction techniques. Subsequently, the life cycling tests will be resumed at NAD-Crane laboratories. The final report is due in November 1971.

Another program to develop larger, 200-AHr cells and high-quality-controlled cell plaques was contracted recently between NASA/Langley Research Center and Heliotech. This work has started and will be completed in 1973.

5. Justification:

Programs to develop 100-AHr cells of high quality will generate representative constant-depth charge/discharge cycling data of value to their comparison, as currently provided on 20-AHr and 36-AHr cells. However, neither will provide the space station environments with the variable load discharge profiles and variable-charge profiles. Nor, will conditional application tests for emergency power capability, or for operation under marginal cooling conditions be performed under the basic programs. Use of the batteries with actual battery-chargers and discharge regulators of space station design, and usage under the operating conditions peculiar to parallel-charging and series-discharging (at 115 volts) can only be demonstrated as part of the Space Station development program where the necessary system elements are available.

6. Technical Plan:

A. Objectives

The objectives of the program will be to provide the comparative data and operating experience on common-test bases that are necessary for selection and application of the 100-AHr cells and batteries for the Modular Space Station program.

B. Technical Approach

1. Review the battery data available from the GAC battery development contract with respect to the MDAC Modulator Space Station electrical load and orbital requirements.
2. Procedure sufficient GAC/Eagle-Picher 4-cell battery modules to test charge/discharge characteristics for 28-cell batteries (7 modules) charged in time-series, and 4-battery strings (each battery having 28 cells discharged in parallel. Test characteristics over a range of charge rates, including sequential charging of batteries to investigate high-rate benefits. Include the fabrication and verification of thermal control (cold plating or other recommended method) techniques for the batteries.
3. Review data from Gulton Industries, from General Electric and other candidate designs offered for comparison with Task 1 data for GAC cells.
4. Perform identical tests under the conditions of Task 2 for Gulton, General Electric, and any other candidate designs offered for comparison with GAC cells.
5. Perform analyses, comparisons, and any additional tests necessary.

6. Provide recommendations for the battery type, manufacturing source, and packaging required for the cold-plating, battery mounting, charge control, discharge control, etc., for the Space Station.
7. Prepare standard specifications for procurement and control of space-qualified batteries to meet the Space Station requirements.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	2	2
Funding			
Engineering	\$100,000	\$100,000	\$100,000
Equipment and Materials	100,000	100,000	100,000
Total	\$200,000	\$200,000	\$200,000

7 A

SRT M13

1. Item: Charge/Discharge Control Techniques

2. Category: Advanced Development

3. Technology Area/Panel: Power

4. Status:

Many charge control methods have been used, many devices such as signal electrodes and ampere-hour meters have been used, and several methods of solar array/battery power conservation methods have been used. All of these types of methods and devices must be evaluated and an optimum concept selected from one or a combination of the items noted above.

A part of the Grumman Aerospace Corp. (GAC) Contract NAS9-11074 is the design and breadboard development of prototype charge control equipment for the cell and battery module test phases. However, a complete charge/discharge control assembly for Space Station application is not included in the program. The charging equipment will be based on 1969 state-of-the-art components, circuitry, and subassemblies, except where high reliability can be identified readily for later technology.

5. Justification:

Batteries represent one of the least efficient parts of the solar array/battery subsystem. Therefore, it is advantageous to design an optimum control for charge and discharge of the battery to assure maximum utilization of solar array output and the most efficient recharge method and rate. Present Skylab batteries utilize 20-ampere-hour (AHr) and 36-AHr cells. Space Station solar array/battery power systems require much larger cells (e.g. 100 AHr) to reduce the number of batteries and cells to be installed, monitored, maintained, and replaced.

Improvements in the reliability of control equipment is essential. Improvements in battery cycle life in the range of 10,000 - 30,000 cycles with depths of discharge in the range of 25 to 35 percent will be enhanced by the development of adaptable charge/discharge control equipment and the proper cell monitoring instrumentation.

6. Technical Plan

A. Objectives

The objective of this program will be (1) to advance the state of the art beyond 1969 by demonstrating high reliability in new charge/discharge control methods, (2) to extend the lifetime and performance potentials of batteries by more effective use of the battery capability, (3) to develop optimum control and instrumentation for use with NiCd batteries; (4) to provide adaptive control techniques for application to random load cycling (see SRT Item, "Random Load Cycling Effects on Batteries").

B. Technical Approach

1. Characterize the current techniques and control equipment as to (1) the modes of control, (2) the sensitivity to battery characteristics, and (3) the adaptability of the control equipment to the changing capability of the 100-AHr battery. These should be described as functions of the state of charge or discharge, the age, and the history and memory of the cells in the battery.
2. Design and breadboard the most promising method(s) from Task 1. This should include the GAC prototype charger defined for the 100-AHr cells. This development should provide a full-scale charger for a 28-cell, 100-AHr battery. The discharge control functions should also be incorporated. Instrumentation for monitoring and provisions for remote control commands in digital form for computer power management should be incorporated also.
3. Test the charge/discharge controller under realistic Space Station loads and solar-array power profiles.
4. Evaluate results, change the controller design, and retest as necessary.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	$150,000	$150,000
Equipment and Materials	200,000	300,000
Total	$350,000	$450,000

1. Item: Random Load Cycling Effects on Batteries

2. Category: Advance Development

3. Technology Area/Panel: Power

4. Status:

Current testing programs are designed for constant-depth discharge and charge cycles and constant rates, usually to provide battery life testing data which is not tailored to or representative of a single application.

5. Justification:

The battery will be subjected to large excursions in electrical loads during their operation for varying durations of time. The random cycling effects may place severe limitations on the batteries if the correlation from random load cycles to constant load cycles is faulty. Therefore, knowledge of the effects on a battery from random load cycling is essential to design the battery and its charger to satisfy realistic load cycling requirements.

6. Technical Plan:

A. Objectives

The objectives of this program are to determine the relationship of random load cycling to constant-load cycling and to determine random cycling effects upon the battery.

B. Technical Approach

1. Develop a test program plan which reflects realistic load-power profiles and solar-array recharge power profiles and which includes battery effect analysis; for example, a program which examines the available charge, charge acceptance capability, and the cycle efficiency at appropriate intervals of time. Control samples will be needed to relate the random cycle effects to the constant cycle effects.
2. Conduct the test program.
3. Analyze the test data and evaluate the effects on the battery.
4. Redesign battery control techniques if applicable and retest.

5. Evaluate the techniques, recommend the best control method, and provide instructions for life predictions and battery charge/discharge management.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2	3
Funding		
Engineering	$100,000	$150,000
Equipment and Materials	200,000	250,000
Total	$300,000	$400,000

SRT M15

1. Item: Power Management by Computer Techniques

2. Category: Advance Development

3. Technology Area/Panel: Power

4. Status:

The basic computer technology is fairly well established for analysis of monitored data, for comparisons with pre-established limits, for display, and for limited decision-making functions. Currently, digital computers are used in power monitoring and power management functions by several power utility companies.

5. Justification:

The crew time and skills onboard are not sufficient to provide full-time supervision and management of the electrical power system. Therefore, computer automation is required. The implementation of computerized power management, as envisioned for the Space Station, will require significant advancement of these techniques, particularly in 1) the areas of required ranges of decision-making and active control functions, 2) dealing with transient or abnormal conditions, 3) providing logic to retain full capability while changing power system configurations, 4) handling a large quantity of routine data while responding correctly to abnormal values or trends of the data, and 5) establishing the optimal degree of crew involvement in the control functions.

6. Technical Plan:

A. Objective

The objective of this program is to advance the technology for applications of computers to the management of electrical power systems; in particular, to systems for which a large number of individual elements are to be monitored and actively controlled according to pre-established patterns. The power management functions will include fault detection and remedial switching, redistribution of loads for optimum energy transfer efficiency, load priority assignments, load scheduling, and visual display of power system status.

The program will also determine the optimum choices and task assignments for Electrical Power System (EPS)-dedicated pre-processors versus central computers.

B. Technical Approach

1. Review the electrical power system design to determine those parameters which must be monitored, those which must be controlled, the acceptable ranges of parameters, and the preferred design point values of these parameters.
2. Establish the requirements for each power system and load sensor, for instrumentation, and for control software.
3. Define the operating conditions for each system element.
4. Design the computer auxiliary equipment and the pre-processor equipment.
5. Fabricate breadboard hardware and perform tests necessary to assure compliance with the requirements.
6. Design and fabricate the control software, and perform necessary tests to assure compliance with the requirements.
7. Develop simulation equipment to simulate the Space Station electrical power hardware and its operating characteristics (under normal steady-state, abnormal, and transient conditions).
8. Integrate the hardware from Tasks 5, 6, and 7 and verify its expected performance.
9. Test the computer power management system by the introduction of control, fault protection, load scheduling, and remedial switching problems.
10. Evaluate the system performance, identify any errors, limitations, control anomalies (or "lockups"), and determine the data processing capabilities.
11. Revise the hardware and software as necessary and iterate the test program.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	3	3	2
Funding			
Engineering	$150,000	$150,000	$100,000
Equipment and Materials	100,000	200,000	100,000
Total	$250,000	$350,000	$200,000

SRT M16

1. Item: Power Regulation System Evaluation

2. Category: Advanced Development

3. Technology Area/Panel: Power

4. Status:

The MDAC Modulator Space Station study selected a sequential, partial-shunt, regulator design for regulation of the solar array power. The NAR Modular Space Station study selected a series pulse-width modulated (PWM) buck regulator followed by inverters for AC transmission. The MDAC Airlock Module/Orbital Workshop (AM/OWS) program has developed integrated charger-regulator hardware based on a series PWM buck regulator through subcontract with Engineered Magnetics Division of Gulton Industries. The MSFC Apollo Telescope Mount (ATM) program has developed an integrated charger-regulator module based on a series PWM buck/boost regulator. The series PWM regulators are adaptations of technology which has been well established by many designs. The sequential partial-shunt regulator concept has been developed by TRW and variations of the elements of the system have been demonstrated by physical testing and by flight on as many as four generations of TRW spacecraft (Reference 1).

5. Justification:

The regulation systems identified above are generally of smaller power capability than are required for the Modulator Space Station. The particular penalty of maximum power loss at maximum power associated with the series regulator is not favorable to the goal of minimizing solar array area to minimize power-system cost. The shunt-regulator concepts, by contrast, dissipate power or divert power only when it cannot be used by the loads and, therefore, provide minimum solar array area and minimum cost. Their relative flexibility for accommodating solar array power capability variations will require demonstration by testing. A program of comparability testing of physical models is necessary to resolve the performance issues

Reference 1: Kimble, S.G., and Wise, J.F., "Integrated Electronics Solar Array Control Unit," 1971 Power Conditioning Specialists Conference, JPL.

and to permit selection of the best regulation system for the Modular Space Station.

6. Technical Plan:

A. Objectives

The objectives of this program are 1) to demonstrate the characteristics, merits, deficiencies, design factors, and the operating and control features of competitive regulator design concepts; 2) to perform system testing on competitive regulator concepts under strictly controlled and repetitive operating conditions; and 3) to determine the proper regulator concept to be incorporated into a Concept Verification Test (CVT) program and the proper methods of control, operation, and checkout to be utilized in the CVT.

B. Technical Approach

1. Perform an analysis of the Electrical Power System (EPS) requirements pertinent to the voltage regulation function.
2. Define the voltage regulator operating conditions.
3. Develop a detailed test plan.
4. Prepare specifications for the sequential partial shunt regulator (SPSR).
5. Procure the necessary regulator assemblies (AM/OWS and ATM); procure the breadboarded or development hardware (SPSR); or prepare the design drawings and fabricate the breadboarded hardware.
6. Determine the EPS elements to be simulated and those to be installed as hardware.
7. Determine the instrumentation and sensor requirements, types of display or recording, the ranges of instrumented parameters, and the allowable measurement tolerances.
8. Develop the software necessary for programmable source and load profiles.
9. Provide supporting engineering during facility installations and hardware development.
10. Check out hardware specification compliance and performance.
11. Perform testing according to the test program plan (Item 3) and iterate both as necessary.
12. Revise programs or hardware as necessary and reiterate the test program.

13. Prepare test evaluations and regulation concept comparisons.
14. Prepare an order-of-preference report and document the program.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	2	2
Funding			
Engineering	$100,000	$100,000	$100,000
Equipment and Materials*	100,000	200,000	200,000
Total	$200,000	$300,000	$300,000

*Test Hardware - Use of existing AM/OWS and ATM regulators

SRT M17

1. Item: Modular Inverter System Development

2. Category: Advanced Development

3. Technology Area/Panel: Power

4. Status:

Modular inverter design studies have been conducted by Westinghouse and General Electric; paralleling technology, real and reactive load sharing circuitry, operating stability, and clock frequency control methods were considered. The basic technology for solid-state inverter design of power ratings at 28 and 56 vdc up to 2.5 kW has been established on NASA, USAF, and submarine-program applications.

5. Justification:

Although the basic technology is established for power inverters supplied at 28 to 56 volts dc input, the unit sizes required for the Modular Space Station with 115 vdc input requires development work to define performance requirements, to mechanize automatic switching of the modules in response to load power demand, and to demonstrate stability, acceptable reliability, operating efficiency and optimal control of characteristics over a broad load range (3 to 1 or greater). Solid-state component development is also needed for 115 vdc input. Development of a sine-wave filtering module also offers the advantages of design commonality for multiple application of the basic quasi-square wave inverter modules.

6. Technical Plan:

A. Objective

The objective of this program is to develop and to demonstrate flexible, solid-state inverter designs based upon switchable parallel modules to operate at nominal input voltages of 115 ± 3 vdc and to efficiently produce 0.5 to 2.0 kWe of 115 to 200 ± 2-1/2 percent vac, 3-phase power at 400 ± 1 percent Hz. These basic inverter designs should provide a quasi-square wave output voltage with conversion to a sine-wave voltage by the addition of filtering and wave-shaping components.

B. Technical Approach

1. Define the system and equipment technical requirements.
2. Establish the optimum unit size for the inverter and filter modules.
3. Design the basic modules of the inverter system.
4. Fabricate development models and test to assure satisfaction of the technical requirements.
5. Evaluate test results, redesign, modify, and retest as necessary. Particular attention is required to assure high system reliability and maintenance of a substantially high efficiency over the full range of switched modules with parallel operation.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	1	2	1
Funding			
Engineering	$ 50,000	$100,000	$ 50,000
Equipment and Materials	50,000	50,000	50,000
Total	$100,000	$150,000	$100,000

SRT M18

1. Item: Solid-State Switching for High Voltage and High Current

2. Category: Advance Development

3. Technology Area/Panel: Power

4. Status:

Present technology in solid-state electronics for space power conditioning equipment encompasses the 28 vdc and, to a limited extent, the 56 (±28) vdc range. Development programs started at 56 and 200 vdc (e.g. the Westinghouse Contract with NASA-LeRC) were later revised to delete the higher voltage range. Capability at 80 vdc (steady state) is presently established and is limited by the transient over-voltage (up to 120 vdc) tolerance specification limits. A 5 kW ac-to-dc converter and switchgear development program was also initiated in FY 1971.

5. Justification:

The current state-of-the-art in electrical power conditioning and distribution for aerospace applications has been virtually stalled for many years at 28 vdc due to (1) the smaller market potential for higher voltage dc equipment as compared with aircraft using lower voltage or 400 Hz, ac, and (2) the relatively short distances involved in spacecraft such as Mercury, Gemini, Apollo CSM, LEM, ATM, or the AM/OWS. Every recent study of advanced Space Station economics and efficiency leads to a preference for some higher voltage such as 115 to 120 vdc. Shuttle and Space Station studies both show substantial merits for this higher voltage, yet do not require major changes in other equipment for the required insulation levels. The raditional reason given for not advancing the voltage from 28 vdc has been a desire for off-the-shelf hardware. It is doubtful that such hardware now exists for the higher current and power ratings or for much of the user hardware needed for the Space Station program. Therefore, a substantial stimulus exists for developing a moderately higher-voltage dc technology.

6. Technical Plan:

A. Objective

The objective of this program is to develop switching components capable of operating at a nominal level of 115 vdc, with transient overvoltage tolerance to approximately 180 vdc, and capable of controlling currents up to 400 amperes DC.

B. Technical Approach

1. Establish design requirements for power and voltage levels, for power quality, and for steady-state, abnormal, and transient performance Power levels of 5 kW, currents of 100 to 400 amperes dc, and voltages up to 120 vdc (approximately 180 vdc transient overvoltage rating) are tentative values.
2. Identify the component hardware and the operating stresses for the switching applications.
3. Design and breadboard the component hardware.
4. Test the components to qualifying stress levels.
5. Redesign and retest as necessary.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	2	1
Funding			
Engineering	\$100,000	\$100,000	\$ 50,000
Equipment and Materials	50,000	50,000	50,000
Total	\$150,000	\$150,000	\$100,000

SRT M19

1. Item: High-Level Power Transfer and Connector Development

2. Category: Advanced Development

3. Technology Area/Panel: Power

4. Status:

Power transfer on most solar-powered NASA and USAF spacecraft to date has been accomplished by flexible cables; a few systems have used reset drives or slip rings. However, all these systems have been low-current, low-speed, shorter-life (up to five years) requirements. Work on liquid metal slip rings has been reported in the research area. Connectors have been developed for standard aerospace applications.

5. Justification:

The flexible cable concept for power transfer between oriented solar arrays and the Space Station will include a large number of conductors of various sizes for power, control, and instrumentation. In addition, flexible liquid lines will be included for solar heat collectors. This complex cable must withstand about 5800 cycles per year at ± 180 deg in the alpha (α) axis and an equivalent number at ± 235 deg in the beta (β) axis, with rotation rates up to 22 deg/minute. A 10-year or longer life requires the flexibility to retain low-resistance torques and high tolerances to fatigue effects with stress cycles up to 58,000 cycles or more.

The technology is limited for large power connectors of the type envisioned for the station module-to-module standardized interfaces. A capability is necessary for connecting or disconnecting these while in a space suit and in space vacuum.

6. Technical Plan:

A. Objective

The objective of this program is to develop a space-qualified flexible electrical cable assembly with integrated connectors and necessary liquid lines, all capable of sustaining 10 years of stress cycling with a high degree of confidence.

B. Technical Approach

1. Determine the conductor sizes, insulation, flexibility, stranding and other construction requirements.
2. Determine the construction and design requirements for connectors.
3. Fabricate test samples of each conceptual design to meet the requirements identified in Tasks 1 and 2.
4. Conduct screening tests up to 1,000 stress cycles and for transient overvoltage and current levels.
5. Conduct life tests (accelerated to the maximum degree which is feasible) for an equivalent of 10 years on the best concepts, as determined by the screening tests.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	2	3	3	2
Funding				
Engineering	$100,000	$150,000	$150,000	$100,000
Equipment and Materials	50,000	50,000	50,000	50,000
Total	$150,000	$200,000	$200,000	$150,000

SRT M20

1. Item: Optical Image Processor

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Single use processors are presently available for ground system usage.

5. Justification:

The advantages inherent in onboard optical Image Processing for realtime analysis and data reduction are dependent upon successful development of a ruggedized system suitable for space usage.

6. Technical Plan:

A. Objectives

Development of a multi-purpose optical impage processor to provide the required flexibility for Modular Space Station.

B. Technical Approach

The concept and design integration of a multi-purpose optical impage processor will be defined. Multi-purpose options will include image orientation changes, image motion correction, provide comparison of several images and other unique functions. Existing single-purpose design concepts will require extensive modification to provide both multi-purpose use and ruggedized optics suitable for space use.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	2
Funding	
Engineering	$100,000
Equipment and Materials	50,000
Total	$150,000

SRT M21

1. Item: Analog Image Processor

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Single-purpose, analog-image processing techniques and equipment exist.

5. Justification:

A flexible and rugged design concept for an analog image processor suitable for space usage must be developed and proved because it is an important component of a complete image-processing subsystem.

6. Technical Plan:

A. Objectives

Development of a multi-purpose, analog, image processor suitable for the flexibility required in the Modular Space Station.

B. Technical Approach

The concept and design integration of a multi-purpose analog image processor will be defined. The processor must perform operations on video signals such as glare and noise removal, contract improvement, and other electronic conversions that are based upon electronic filtering. The processor will be designed to pass analog images through various filters in a sequence determined by an operator to achieve the image processing desired.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	2
Funding	
Engineering	$100,000
Equipment and Materials	50,000
Total	$150,000

SRT M22

1. Item: Image Processing Executive Program

2. Category: Advanced Development

3. Technology Area/Panel: Information System

4. Status:

The results from the Computer Simulation of Model of Image Processing System will be utilized to develop the image processing executive program.

5. Justification:

Results from the simulation model and the early development of an image processing executive program will assure the availability when required for the Modular Space Station program. This advanced development of an executive program will also be useful for hardware/software debugging at an early stage to reduce design changes later.

6. Technical Plan:

A. Objectives

Development of the design for a space-borne image processing subsystem executive program.

B. Technical Approach

Functional flow charts for the image-processing executive program will be developed using the results from simulation of the image-processing model. The program will be developed in a manner to provide for independent definition and development of image processing application algorithms for individual experiment needs. A directly related SRT is "Computer Simulation of Model of Image-Processing Systems."

7. Resource Requirements:

	FY 1974
Manpower (man-yr)	0.6
Funding:	
Engineering	\$30,000
Equipment and Materials	0
Total	\$30,000

SRT M23

1. Item: Computer Simulation of Model of Image-Processing System

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Computer facilities and programming capability presently exists for performance of this simulation. No new simulation techniques are required.

5. Justification:

   (1) Trade studies can be performed more accurately and at lower cost.
   (2) New concepts can be verified before hardware is built, thus reducing costs.
   (3) The initial debugging of computer programs can be done by the simulation at a lower cost.
   (4) New concepts can be developed using the simulation on line. This type of development cannot be done any other way.

6. Technical Plan:

   A. Objectives

Development of a computer program to simulate a model of an image-processing system suitable for the Modular Space Station.

   B. Technical Approach

The computer simulation program will be developed so that alternate processing methods can be simulated and the ones selected can be used in the development of the final image-processing executive program. The simulation will be designed to permit easy modification to incorporate new processing techniques as they are conceived to assess their value. The simulation will also be used to assist in design verification of conceptual designs of space-borne image processing systems. A directly related SRT is "Image Processing Executive Program."

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	2
Funding	
Engineering	$100,000
Equipment and Materials	0
Total	$100,000

SRT M24

1. Item: High-Density Magnetic Recording

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Although, in general, magnetic tape recording is quite advance and has flown successfully in previous space programs, the level required to handle the Modular Space Station requirement has been demonstrated only in a laboratory. The laboratory capability demonstrated is as follows:

Density: $= 1\text{-}5 \times 10^6$ bits/in.^{2}
Recording Rate: $= 2 \times 10^7$ bits/sec
Access Time: = 2-3 seconds maximum at 1,000 in./sec tape speed

5. Justification:

Magnetic tape provides a weight and volume advantage over other widely used bulk data-storage techniques. Existing laboratory capability must be developed into a space flight unit to meet Modular Space Station requirements.

6. Technical Plan:

A. Objectives

Development of a high-density magnetic tape recorder with capabilities for the Modular Space Station.

B. Technical Approach

The ability to record multiple data tracks at extremely high bit densities on magnetic tape has been demonstrated in the laboratory. These high-bit densities have been obtained by the use of "herringbone recording techniques;" in this application two signals are recorded on the same track by successively angling the recording head through at ±45 deg angles. This high density magnetic tape technique seems to be the most promising candidate for meeting the bulk storage requirements of the Modular Space Station. Development for space flight will require modifications of existing laboratory models. For example, modification to cartridge loading should be made and a capability to operate at tape speeds lower than 1,000 in. per sec without degrading bit density capability. Also, solutions must be found for problems such as positioning, i.e., the ability to readdress given data bits without error.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	$150,000	$150,000
Equipment and Materials	50,000	50,000
Total	$200,000	$200,000

SRT M25

1. Item: Multipurpose Displays

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

A development program has reached the stage where this type of multipurpose display device has been demonstrated to justify the continued development of the device to attain its full design potential. To date, 275 lines per inch at 100 percent modulation, 38:1 (11 tones) contrast ratio, 12 msec erase time, 30 msec development time, 10 percent degradation after 30 minutes and 2,000 lumens open gate for a 10-inch display has been demonstrated.

5. Justification:

This type of multipurpose display device will obviously reduce the number of types of displays required, permit simple redundancy for backup considerations, minimize logistics, simplify maintenance and repair, provide optimum viewing conditions, and reduce operational complexity for the Modular Space Station.

6. Technical Plan:

A. Objectives

Development of a multi-purpose display device for the Modular Space Station.

B. Technical Approach

Continue development of multi-purpose displays which can present the data generated by a variety of analog and digital sensors, as well as by digital computers. The multipurpose display will include electrically controlled persistence to provide storage and erase times ranging from a few hundredths of a second for television to minutes for image-freeze, high-resolution, high-brightness, high-dynamic range, freedom-from-distortion, and multiple-scan formats.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	5
Funding	
Engineering	$250,000
Equipment and Materials	50,000
Total	$300,000

SRT M26

1. Item: Integrated Display Techniques

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Digital computers, display generation and transmission equipment using digital television techniques, cathode ray tubes and other system components are currently available to permit a thorough investigation of computer-controlled integrated display requirements.

5. Justification:

Optimized development of electronic, computer-controlled, integrated displays can relieve flight crews of repetitive, routine, and time-consuming activities and maximize use of man's unique decision making and interpretive capabilities.

6. Technical Plan:

A. Objectives

Development of integrated display techniques suitable for the Modular Space Station.

B. Technical Approach

Dynamic simulations of various operational modes will be performed making use of primarily existing display devices and multifunction controls integrated into a breadboard test setup and an existing computer system. The integrated displays will be presented on CRT's under computer control on demand by an operator. Display formats will be made from a selection of alphanumerics, graphics, vectors, and symbols that will best convey to the crew a complete and easily comprehensible picture to permit effective monitoring and control of selected functions. The software and digital logic techniques necessary to interface the computer and the integrated display breadboard will be developed.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	5	5	5	5
Funding				
Engineering	$250,000	$250,000	$250,000	$250,000
Equipment and Materials	0	50,000	50,000	50,000
Total	$250,000	$300,000	$300,000	$300,000

SRT M27

1. Item: Laser/Holography Storage Technique for Bulk Data*

2. SRT Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Storage densities of 10^5 to 10^6 bits per sq in. are currently being achieved in the laboratory by accessing with light-emitting diodes. Capacities of 10^5 to 10^6 bits and access times of 100 to 150 nanoseconds are being achieved with incoherent diodes. With losing (coherent) diodes, response times of 10 nanoseconds are typical. However, cooling problems are restrictive.

5. Justification:

The primary benefit of laser/holography bulk storage is high-density. If the ultimate capability of photosensitive material of 10^9 bits per sq in. can be achieved, 10^{14} bits of digital data can be stored in a total volume of 1 to 2 cu ft. Holography is also immune to degradation from dust and dirt. However, at the present time, techniques using holograms are the least developed of any storage approach.

6. Technical Plan

A. Objectives

Development of laser/holography techniques for storage of large quantities of digital data.

B. Technical Approach

Development of digital data storage devices for bulk digital data will be based on current hologram technology. It has been recognized for some time that photographic material has the highest information packing density of any present storage medium. However, storing information by conventional photographic methods suffer from two major drawbacks; (1) long access time due to the mechanical nature of the medium and (2) sensitivity to dust and scratches due to the easily-obscured nature of the fine detail carrying the information. Using the photographic emulsion to record holograms rather than photographs eliminates these drawbacks. The holograms, when illuminated by a laser beam, produce an image comprised of interference patterns at a certain point in space. These patterns are detected by a detector array, resulting in a direct digital readout.

Development is required in several known areas to take full advantage of the high-information-density capability of photo-sensitive materials by use of laser holography techniques. The ultimate density of photo-sensitive materials can be as high as 10^9 bits per sq in. The capacity of a storage device is presently limited by the detector array to a density of 10^5 to 10^6 bits per sq in. Another limitation is an efficient means of accessing the hologram at high speed. The use of lasing diodes appear to be a promising solution. However, all present lasing diodes must be cooled to 70 to 150°K. Solutions to these problems and others unknown at present must be found.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	3	3	4
Funding			
Engineering	$150,000	$150,000	$200,000
Equipment and Materials	0	50,000	50,000
Total	$150,000	$200,000	$250,000

*Recommended for Growth Space Station Application

SRT M28

1. Item: Checkout Parameter Sensing and Associated Calibration Techniques

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

There have been no known studies which have investigated the methods and techniques for maintaining the calibration of manned space vehicle equipment on a long duration mission. Sensor technology for short duration missions is well developed, but the usage of conventional in-flight sensors may be limited on the ISS because of their accuracy, reliability, and/or location.

5. Justification:

There is a need to investigate existing and advanced sensing techniques to determine their suitability for ISS applications, and to identify the methods to be used in maintaining the calibration of sensing devices to a certified, standard level during the ISS mission. Success of the mission depends upon accurate information which, in turn, depends upon proper calibration of ISS equipments.

6. Technical Plan:

A. Objectives

Determine the suitability of conventional in-flight sensors in ISS applications and identify any new devices that must be developed. Identify devices to be used as onboard calibration standards and develop methods for their application in calibrating ISS equipments. The methods selected should not place undue constraints on the crew or on ISS operations. Methods amenable to computer control or other forms of automation are preferred.

B. Technical Approach

The most suitable devices to be used for ISS subsystem checkout parameter sensing will be defined first, followed by an investigation of possible calibration sources and application methods. The effort will conclude by recommending the means to be provided for in-flight recalibration of ISS equipments.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2.5	1
Funding		
Engineering	$125,000	$ 50,000
Equipment and Materials	25,000	0
Total	$150,000	$ 50,000

SRT M29

1. Item: High-Gain Antenna System Maintenance

2. Category: Advance Development

3. Technology Area/Panel: Information Systems

4. Status:

Operational high-gain antenna systems have flown on many space vehicles. Some, like those on the Apollo spacecraft, have relatively short operating lifetimes. The mechanically despun Earth coverage antenna on communications satellites have been designed for operating lifetimes up to 3 to 4 years. Some have experienced no problems, while others have been suspected to have "freeze-up" problems. Both DOD and NASA have been funding bearing lubrication studies and development. Because all programs with the exception of Apollo have been unmanned, little or no attention has been paid to developing a maintainable high-gain antenna system.

5. Justification:

Because the Space Station has a 10-year operational lifetime, it would be unrealistic to expect the electromechanical drive and positioning system of the high-gain antenna to perform without failure or degradation in performance.

6. Technical Plan:

A. Objectives

The objective of this effort is to determine the level to which space maintenance can be performed and redundancy can be built in to spaceborne high-gain antenna systems.

B. Technical Approach

Tradeoff studies comparing the various types of drive trains and motors will be conducted. This will include evaluation of direct and harmonic drives, ac and dc servo motors, and stepper motors. The use of parallel drive trains will be investigated. Techniques for realigning the system after component replacement will be identified. Detailed assembly and disassembly procedures for the selected system will then be developed.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	2
Funding	
Engineering	$100,000
Equipment and Materials	25,000
Total	$125,000

SRT M30

1. Item: High Gain Antenna Acquisition and Tracking

2. Category: Advance Development

3. Technology Area/Panel: Information Systems

4. Status:

The "high-gain" antenna systems currently being flown on the Apollo spacecraft and communications satellites, such as the Intelsat IV series, have beamwidths of 4 to 5 degrees. These beamwidths are almost an order of magnitude greater than the high-gain antenna system beamwidth of 0.6 degrees required for the Modular Space Station. The Apollo directional antenna system is a tracking antenna, while those utilized by synchronous communications satellites are pointable over a limited range via ground commands.

5. Justification:

The Modular Space Station program will utilize a data-relay satellite system to provide near-continuous wideband communications to the ground. Both the Space Station and relay satellite will require narrow-beamwidth antennas to provide this capability. Therefore it is necessary to develop suitable high-gain antenna acquisition tracking techniques and procedures. There are no currently operational space programs which require space-to-space narrow beamwidth communications from which to draw flight experience.

6. Technical Plan:

A. Objectives

The objectives of this proposed task are to determine the best acquisition and track technique, produce antenna steering software and procedures, and perform tests utilizing prototype Space Station hardware. NASA, MSC, has recently awarded a computer simulation study contract for a high-gain antenna system. The results of this study would be utilized in the proposed task. To satisfy the objectives, the following tasks will be performed:

1. Tradeoff candidate RF acquisition and track methods.
2. Develop and exercise software required for each steering method.
3. Demonstrate prototype hardware compatibility.

4. Identify and find solutions to the problems uncovered during the tests.

B. Technical Approach

The proposed effort is to be conducted in two phases. The first phase will utilize the MDAC On-Line Subsystem Facility (OLSF) to develop the software required for each of the candidate approaches, test the compatibility of the developed prototype hardware, and identify the problems associated with each technique. In the second phase, the Space Station prototype hardware, a tracking antenna system, and steering software will be integrated into the Concept Verification Test (CVT) Facility. Then open-loop tests will be performed to verify the acquisition and track techniques and procedures selected.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	1.75*
Funding	
Engineering	$100,000*
Equipment and Materials	0
Total	$100,000

*OLSF portion only, Hardware and Materials assumed to be supplied by CVT.

SRT M31

1. Item: Advanced Electronic Packaging and Installation Techniques

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Past and present space programs have utilized electronic equipment as developed by each supplier or vendor without any attempts at interchangeability or standardization at levels lower than major component level. Studies have been conducted to define a packaging and installation technique that allows for a standardized family of modular subassemblies and assemblies that permit ease of on-orbit maintainability and replacement.

5. Justification:

Maintenance and replacement of electronic components is planned to achieve the 10-year lifetime objective of the Space Station. This replacement requires an orderly, fast method to minimize crew effort and time. Developing a series of standardized modules will provide this replacement capability as well as reduce the development and qualification testing cost considerably for all electronic equipment.

6. Technical Plan:

Continue and expand existing studies to evaluate standardized modules using LSI, MSI, and discrete piece parts having wide application and potential for implementing into hardware assemblies. Determine level of integration feasible using the components for standardized module development considering crew replacement, quick disconnect capability and integrated cooling. Evaluate various packaging designs and develop specifications for individual vendors to build standardized modules. This specification should include thermal interchange, EMI suppression, material and component selection, maintenance/mechanical, and reliability requirements. Fabricate and evaluate a mockup of the standardized packaging and installation approach.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	3	4
Funding			
Engineering	$100,000	$150,000	$200,000
Equipment and Materials	50,000	50,000	100,000
Total	$150,000	$200,000	$300,000

SRT M32

1. Item: Software Reliability

2. Category: Advanced Development

3. Technology Area/Panel: Information Systems

4. Status:

Statistics and categorization of failure and failure types have not been generated or used to define computer program production aids. Documentation standards exist but are not uniform within industry or Government software production organization.

5. Justification:

The criticality of software in support of computer systems requires emphasis on production methods to ensure error free delivered products. Historically, software production methods and validation procedures for real time systems are unique to each development and each computer system. The cost of software development has surpassed the hardware counterpart without the required emphasis upon development aids supportive to cost reduction.

6. Technical Plan:

A. Objectives

The objective of software reliability analysis is to itemize factors that contribute to software unreliability, develop a means for assessing these factors, and develop corrective procedures or production aids.

B. Technical Approach

The failure and correction reports from Government and industry will be collected and analyzed. The data will be purified, failures classified, key parameters identified, and empirical statistical and deterministic models developed. Then the failure characteristics will be used to formulate:

(1) improved procedures for program checking,
(2) mathematical techniques for proving programs correct,
(3) automatic debugging tools,
(4) quality control procedures, and
(5) configuration management systems.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	4	3	2
Funding			
Engineering	$200,000	$150,000	$100,000
Equipment and Materials	0	0	0
Total	$200,000	$150,000	$100,000

SRT M33

1. Item: Long-Life Pressure Cabins

2. Category: Advanced Development

3. Technology Area/Panel: Materials and Structures

4. Status:

Data on long-life pressure cabins for space application is very limited; thus several aspects in this area warrant consideration. Pressure cabin metallic structural materials under load vs. prolonged (in excess of 10 years) exposure to space is not expected to present a major problem, but long time test verification is needed.

The ability of Space Station Module basic structure to withstand damage without catastrophic rupture is required. Data in this area is very limited; however, aircraft fail-safe and safe-life work is a good precursor to the needs for space vehicles. MDAC is also developing such a fail-safe concept.

The Space Station Module windows must be able to withstand space exposure and impact damage without catastrophic rupture. This requires the development of fail safe concepts which may use existing materials. The development of new materials may also be required for this application.

5. Justification:

Future manned space vehicles will be designed for long life -- either reusable for many years or on orbit life of many years. The integrity of the vehicle depends upon a structural system which has a verified safe-life expectancy for the duration of specified missions.

6. Technical Plan:

   a) Prepare design concepts for typical long life manned spacecraft pressure vessels (shuttle launched).
   b) Determine effect of continued exposure to space environment, for long periods, of candidate metallic materials and candidate window materials.

c) Determine cause and effects of damage during desired life - meteoroid, crew inflicted, machinery malfunction and fatigue and stress corrosion (reusable vehicles).

d) Conduct test of damaged structures to insure adequate damage resistance or fail safe design.

7. Resource Requirement:

	FY 73	FY 74	FY 75
Manpower (man-yr)	4	6	4
Funding			
Engineering	$200,000	$300,000	$200,000
Material and Test	100,000	300,000	300,000
Total	$300,000	$600,000	$500,000

SRT M34

1. Item: Long-Life Pressure Tanks

2. Category: Advanced Development

3. Technology Area/Panel: Materials and Structures

4. Status:

The Space Station Modules will require storage tanks within several individual subsystems. Some of these tanks will be exposed to space and others will be contained in pressure cabins; all of them will be in use for years with repeated pressure cycles and very little data exists for such applications. Rupture of such tanks may result in loss of a complete vehicle from the pressure rise in confined region or from shrapnel causing further damage.

5. Justification:

Improper design for long life could result in crew fatalities and/or vehicle loss. New methods of tank construction, the use of armor plating and mail chain shrouds are potential considerations.

6. Technical Plan:

Conventional pressure tanks will be analyzed for life expectancy considering applicable number of cycles during a lifetime. Appropriate factors of safety and proof pressures will be determined. Similar analysis and long life tests of tanks in space environment will be verified. In the event of unpredictable failure, a new type of construction which splits or tears rather than producing high-speed shrapnel will be tested. Light weight shrapnel barriers will be tested.

7. Resource Requirements:

	FY 73	FY 74	FY 75
Manpower (man-yr)	2	4	2
Funding			
Engineering	$100,000	$200,000	$100,000
Material and Test	50,000	200,000	100,000
Total	$150,000	$400,000	$200,000

SRT M35

1. Item: Dynamic Seals
2. Category: Advanced Development
3. Technology Area/Panel: Materials and Structures
4. Status:

Preliminary tests at MDAC have shown that low leak rates and low friction can be achieved in rotating seals. Further development to evaluate candidate materials for low maintenance and long life are required.

5. Justification:

Solar array gimbals for the power module will require vacuum sealing rotating joints. Neither significant atmospheric leakage nor high friction is acceptable.

6. Technical Plan:

   a) Evaluate candidate materials in a test fixture similar to the one in use at MDAC.
   b) Determine choice of seal material to insure long life and low maintenance.

7. Resource Requirements:

	FY 73	FY 74	FY 75
Manpower (man-yr)	1	2	1
Funding			
Engineering	$50,000	$100,000	$ 50,000
Material and Test	20,000	50,000	50,000
Total	$70,000	$150,000	$100,000

SRT M36

1. Item: Docking Systems

2. Category: Advanced Development

3. Technology Area/Panel: Materials and Structures

4. Status:

Several viable docking systems are proposed for use in the space station program. The need for a universal system has been defined. Little work has been done on the required scale to analyze and test the dynamics of docking impact and its effect on the control system and vehicle response.

5. Justification:

Development of a universal system which is adaptable to many vehicles will take considerable time in design, construction and test. If a universal system is adopted, it will be needed well in advance of the space station.

6. Technical Plan:

The Space Station Modules which will require a docking system for lock up in space must be summarized and detail requirements for docking systems defined. One, or at most two, systems should be designed and analyzed. The preferred system should be built to full scale and tested for its impact and dynamic performance.

7. Resource Requirements:

	FY 73	FY 74	FY 75
Manpower (man-year)	10	10	10
Funding			
Engineering	$ 500,000	$ 500,000	$500,000
Material and Test	500,000	500,000	200,000
Total	$1,000,000	$1,000,000	$700,000

SRT M37

1. Item: Meteor Impact on Biaxially Stressed Materials*

2. Category: Advanced Development

3. Technology Area/Panel: Materials and Structures

4. Status

Considerable design analysis and test data exists on the effect of meteoroid impact on passive targets, unshielded and shielded. Some tests have been conducted on pressurized cryogenic tanks at cryogenic temperatures. However, little information exists on the extent of damage when hypervelocity projectile come in contact with targets such as a pressurized module.

5. Justification:

Extent of damage to biaxially stressed pressure cabins may be much more severe than the current penetration probabilities indicate.

6. Technical Plan:

Initially some tests will be made of uniaxially stressed flat panels to evaluate effect of penetration of materials under load. Extent of damage, i.e., critical flaw produced will be evaluated for existing candidate Space Station Module pressure vessels. These structures would be redesigned, as necessary, and biaxially stress specimens would be penetrated to determine threshold of fail safe designs.

7. Resource Requirements:

	FY 73	FY 74	FY 75
Manpower (man-yr)	4	2	2
Funding			
Engineering	$200,000	$100,000	$100,000
Material and Test	100,000	50,000	50,000
Total	$300,000	$150,000	$150,000

*Note: This work must be coordinated with SRT Item "Long-Life Pressure Cabins."

SRT M38

1. Item: Adaptive Controller

2. Category: Advanced Development

3. Technology Area/Panel: Control

4. Status:

The application of adaptive control concept to flight controllers have been proven in aircraft and in missiles to some extent but application to spacecraft control has not been exploited to any significant level. The Space station is a new application requiring use of the adaptive approach because of the large change in mass properties that occur during the mission.

5. Justification

An attitude control design approach which adapts to the variable plant characteristics (Modular Space Station mass, inertias, cg., location and disturbance profiles) to provide constant control performance is an adaptive attitude controller. This controller measures some state of the plant which is related to an attitude control performance index and adjusts the controller gain or other parameters to maintain a level of control performance while the plant undergoes changes. These changes occur as a result of mass depletion, docking, undocking, configuration changes, etc. This type of controller is required for the Modular Space Station because of the numerous combinations of modules forming the orbital configuration and this requires several conventional controller designs to satisfactorily provide a consistent level of performance. Further, adaptive controller can survive Modular Space Station configuration changes during the design phase or during the buildup phase (due to operational changes or launch aborts) without causing major alterations.

6. Technical Plan:

A. <u>Objectives</u>

Provide the control system designer with techniques for adaptive controller design for the variable mass Space Station. This SRT program should yield evaluation and simulation data for candidate techniques with software and interface requirements definition.

B. Technical Approach:

Analytical techniques and concepts for adaptive controller design will be available at start of this SRT program. A design approach for the variable plant characteristics will be formulated. Simulation of the adaptive scheme will be required for the control system performance. Techniques for parameter estimation and control gain modifications will be defined. The acceptable regions of the critical parameters and characteristics will also be identified.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	4	4
Funding		
Engineering	$200,000	$200,000
Equipment and Materials	0	0
Total	$200,000	$200,000

SRT M39

1. Item: Onboard Sensor Alignment, Calibration, and Maintenance

2. Category: Advanced Development

3. Technology Area/Panel: Control

4. Status:

Concepts exist for onboard alignment monitor using both optics and electronics but have not been applied to spacecraft.

5. Justification:

Alignment and calibration will be required to align and measure the relative angle between the GNC sensors and a common benchmark on the Modular Space Station. Due to the relatively long-mission duration of the Modular station, GNC sensor replacement and realignment will be required.

The alignment and calibration insures a consistent attitude accuracy of the stations benchmark throughout the mission duration in which the GNC sensors may be replaced several times. The attitude reference data generated at the sensors are applicable to that location and do not account for the relative misalignments which exist between sensors and other equipment. The benchmark alignment and calibration will eliminate one source of error. Application of this technique may be extended to alignment of remote experiment sensors.

6. Technical Plan:

A. Objectives

Techniques and design approaches for monitoring relative alignments of Modular Space Station equipment with respect to a common benchmark are to be identified. The spacecraft attitude reference is assumed to be the benchmark and all other equipments are to be aligned and alignment monitored relative to this benchmark.

B. Technical Approach

1. Establish the onboard alignment and monitor requirements.
2. Define the candidate techniques to be used for alignment and monitor. (Concepts exist using both optics and electronics.)

3. Determine performance and trade factors for the concepts selected.
4. Develop preliminary alignment monitor design.
5. Define performance of selected techniques.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	3
Funding	
Engineering	$150,000
Equipment and Materials	50,000
Total	$200,000

SRT M40

1. Item: Rendezvous Sensor Improvement*

2. Category: Advanced Development

3. Technology Area/Panel: Control

4. Status:

Current capability for accurate medium range tracking does not exist.

5. Justification:

The range at which optical sensors can track a target is presently about half the value required (100 nmi) for Modular Space Station application. This capability must be extended. In addition, the demonstration of the optical tracking system in an overall rendezvous system in the space environment has not yet been accomplished satisfactorily. A reduction in physical size is also a desired goal. This field of view is at best marginal for rendezvous application. The primary application of this rendezvous aid is in remote control of free-flying modules (station keeping) from the space station.

6. Technical Plan:

A. Objectives

The optical tracker is important in automatic docking and would likely be included for that purpose. If the range and field of view of the optical device is marginal or inadequate to handle the phases of rendezvous within 100 miles of the Space Station, another ranging device will be required.

B. Technical Approach.

1. Establish baseline mission and rendezvous range requirements.
2. Investigate methods for extending the tracking range of the optical tracking system.
3. Define candidate ranging devices.
4. Perform the trade studies for the selection of the tracking range system and provide the performance, cost, and system operation procedures.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	6
Funding	
Engineering	$300,000
Equipment and Materials	0
Total	$300,000

*Recommended for growth Space Station application

SRT M41

1. Item: Solar Cell Energy Wheel System

2. Category: Advanced Development

3. Technology Area/Panel: Control

4. Status:

Currently, flywheel storage concepts are being evaluated by the Air Pollution Control Office of the Environmental Protection Agency and Bellcom has proposed concepts applicable to orbiting spacecraft.

5. Justification:

The Solar Cell Energy Wheel System (SCEW's) performs the dual functions of electrical power storage/generation and the momentum storage function of the attitude control subsystem. The application of SCEWs to a range of manned and unmanned spacecraft should be evaluated and compared with present concepts, such as battery storage and separate momentum storage control units.

6. Technical Plan:

A. Objectives

Establish the feasibility of SCEWs to perform the dual functions of electrical power storage/generation and momentum storage function for attitude control.

B. Technical Approach

1. Establish baseline space vehicle mission models. Establish SCEWs requirements for each case.
2. Determine SCEW's sizing and control logic approaches.
3. Determine parametric SCEWs characteristics.
4. Assess impact of alternate baseline power systems and type of power.
5. Develop preliminary SCEWs design/integration with mission vehicles.
6. Compare SCEWs designs with baseline subsystems.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	6
Funding	
Engineering	$300,000
Equipment and Materials	0
Total	$300,000

SRT M42

1. Item: Solar Panel Dynamics

2. Category: Advanced Development

3. Technology Area/Panel: Control

4. Status:

A study is presently in progress by Fairchild Industries in Germantown, Md. on Contract NAS1-10155 to NASA-LRC (Langley Research Center). The Fairchild study is constrained to the zero "g" mode of operation, and covers large flexible solar cell arrays. It analyzes force interactions between the array and the Space Station. It is formulated to (1) provide analytical methodology, (2) analyze two-array structural concepts, and (3) determine Space Station perturbations caused by array force interactions. The attitude control system model is composed of Control Moment Gyros (GMG's) and reaction jets. Calculated array structural dynamic properties are included, but the Space Station proper is considered to be a rigid body. Time-dependent forcing functions are used for inputs to the dynamic system computer analysis.

A limited analog analysis about the pitch axis of the Space Station has been completed by MDAC. Further, more complete analyses are required about the roll axis and for both rigid and rollout arrays. Data are also required for interaction between panels of an array.

5. Justification:

A solar panel must have the capability to withstand the dynamic environment (g-loads, frequencies, etc.) imposed upon it from interaction between the control system, the space vehicle, the deployment booms, the solar panels, and the cells and interconnectors. The dynamic characteristics are necessary to ensure proper design of either rigid or rollout solar panels. The NASA-LRC study presently incorporates out-of-plane disturbances only, whereas in-plane disturbances are also expected (e.g. during docking and during unmanned periods). The force and frequency regimes require review to accommodate appropriate input and response parameter ranges for steps of Modular Space Station build-up.

Methods of physical modelling with reduced scale and physical testing should be undertaken to demonstrate and/or verify analytical results at lower cost. Continuing analyses should incorporate the evolving designs of the Lockheed Missile and Space Company (LMSC) solar array under Contract NAS9-11039 and of the Space Station under Contract NAS8-25140.

6. Technical Plan:

A. Objective

The principal objectives of this program are to provide a specific dynamic assessment of the selected Space Station/solar array design configuration, to verify the adequacy of design, to provide guidance to station operational methods and constraints, and to provide guidance to interface designs.

B. Technical Approach

1. Prepare analytical models for the elements of the solar arrays, for the Space Station at different stages of buildup, for the control systems in both pitch and roll axes, and for the sources of dynamic perturbation.
2. Establish the nature and magnitudes of the dynamic stimuli (e.g. docking, propulsion, crew motion, and equipment handling) and of the major response modes in the control system, structure, and solar arrays.
3. Conduct computer analytical studies to include roll axis, pitch axis, and combined roll and pitch axis modes of dynamic disturbances.
4. Evaluate bending frequencies and deflections, identify system instabilities, and determine interactions of booms, masts, panels, wings or arrays with the station attitude control system or other systems.
5. Conduct further studies as in Tasks 3 and 4 for three-axis disturbances (i.e. combining the effects of coupled pitch, roll, and yaw).
6. Assess stability margins for a linearized coupled system to identify gain and phase margin allowances for the control system.
7. Determine scaling factors and fabricate scale models to simulate the solar array design.

8. Subject the scale models to the scaled perturbations and measure the response characteristics. Compare the result with the analytical results of prior tasks.
9. Correlate the analytical and the scaled physical model test results and evaluate compliance of the solar array designs with Space Station dynamic requirements.
10. Redesign and reiterate the prior tasks to obtain an acceptable design.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	$150,000	$150,000
Equipment and Materials	50,000	50,000
Total	$200,000	$200,000

SRT M43

1. Item: Biowaste Resistojet (Engine and System)

2. Category: Advance Development

3. Technical Area/Panel: Control

4. Status:

Biowaste resistojet thrustors are under development by several companies; however, they have not reached the operational phase. A prototype propellant collection and control system is under development.

5. Justification:

The use of a biowaste resistojet system provides a useful method of biowaste disposal, while minimizing propellant resupply requirements for orbit keeping and control moment gyro desaturation. This approach maximizes operational flexibility, reduces spacecraft contamination and is compatible with either open or partially closed oxygen EC/LS cycles.

6. Technical Plan:

A. Objective

To develop a prototype biowaste resistojet system capable of operating with an EC/LS system to establish the effects of integration and necessary interface requirements.

B. Technical Approach

1. Develop thrustors with high performance and electrical efficiency.
2. Develop a prototype propellant collection and control system compatible with both the thrustor requirements and the EC/LS interface.
3. Integrate the propellant collection and control system with thrustors and test as required.
4. Integrate the total Resistojet Subsystem with an EC/LS Subsystem and test as required.

7. Resources Required:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	4	3	3	4
Funding				
Engineering	$200,000	$150,000	$150,000	$200,000
Equipment and Materials	300,000	250,000	250,000	300,000
Total	$500,000	$400,000	$400,000	$500,000

SRT M44

1. Item: Monopropellant Thrustors (N_2H_4)

2. Category: Advance Development

3. Technical Area/Panel: Control

4. Status:

Numerous monopropellant (N_2H_4) thrustors have been developed for specific applications. In general, lifetime requirements have not met Space Station needs with regard to total firing time and/or number of pulses. As a result testing has not been carried beyond the specific life requirements and the actual expected life is not known.

5. Justification:

The proof of useful life of existing designs and for specific long life designs will provide information necessary to make an accurate estimate of maintenance, spares and resupply costs. The penalties involved with EVA maintenance and replacement of thrustors may be accurately traded with the costs of other schemes that may eliminate EVA.

6. Technical Plan:

   A. Objective

To develop a 25-lbf N_2H_4 monopropellant thrustor with a 5-to-10-hour life. Firing durations of 0.030 to 1000 seconds must be accommodated with 90 percent of the total impulse derived from minimum impulse burns. I_{sp} should exceed 180 sec at 0.030 sec duration and 230 sec at 5 sec or greater duration.

   B. Technical Approach

      1. Select promising existing thrustor design of approximately 25 LBF and test to determine actual life under pulsing (0.030-sec) burns.
      2. From results shown above, implement necessary design improvement and retest as required.

3④

7. **Resource Requirements:**

	FY 1973	FY 1974	FY 1975	FY 1976	FY 1977
Manpower (man-yr)	2	3	4	5	1
Funding					
Engineering	$100,000	$150,000	$200,000	$250,000	$ 50,000
Equipment and Materials	100,000	150,000	200,000	200,000	100,000
Total	$200,000	$300,000	$400,000	$450,000	$150,000

SRT M45

1. Item: Maintenance, Resupply, Propellant Transfer

2. Category: Advance Development

3. Technical Area/Panel: Control

4. Status:

Limited tests and analysis have been performed, however, the system requirements have been quite different than the Space Station requirements. Effort regarding purging of propellant lines to make or break connections for resupply or repair under zero-g conditions has not been initiated.

5. Justification:

Methods and procedures must be developed for use during Space Station maintenance. The results of this study will help determine the system modifications, support equipment, and skills required to perform repair or resupply tasks.

6. Technical Plan:
   1. Develop a general method to handle purging and hook-up of liquid lines that would be applicable to common Space Station fluids.
   2. Determine effectivity of a vacuum purge to clear lines and components as the studies progress.
   3. Build model systems for use in flight experiments to prove effectivity of methods.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976	FY 1977
Manpower (man-yr)	1	1	3	4	2
Funding					
Engineering	$ 50,000	$ 50,000	$150,000	$200,000	$100,000
Equipment and Materials	50,000	50,000	200,000	500,000	250,000
Total	$100,000	$100,000	$350,000	$700,000	$350,000

SRT M46

1. Item: Optical Fine Pointing of Manned Space Experiments

2. Category: Advanced Development

3. Technology Area/Panel: Control

4. Status:

The technology for fine pointing of manned instruments has been developed for ATM and other programs, it only requires application and refinement of the techniques developed.

5. Justification;

Study and development is required to extend the fine-pointing capabilities for space telescopes. The task will define fine-pointing techniques including carrier pointing and stability, use of flexure gimbal systems and other suspension techniques, and fine pointing and stability augmentation within the telescope experiment. Offset and bore-sighted reference sensor techniques will be included.

6. Technical Plan:

The tasks associated with this item are to develop techniques and prototype hardware for achieving fractional arc second pointing accuracy and stabilities of 0.5 to 0.005 arc-sec for telescopes involving man.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	7	10
Funding			
Engineering	$100,000	$350,000	$ 500,000
Equipment and Materials	150,000	400,000	500,000
Total	$250,000	$750,000	$1,000,000

SRT M47

1. Item: Waste Collection and Sampling

2. Category: Advance Development

3. Technology Area/Panel: Bio-Research

4. Status:

Available collection and sampling methods are difficult to use, unpleasant and inaccurate; none are suitable for both males and females; contamination control is poor and sampling requirements are poorly defined. State-of-the-art is essentially on the Gemini level.

5. Justification:

All manned space programs require the collection and sampling of fecal and urine excreta. Although current methods have been unsatisfactory since the Gemini program, little advance in the state-of-the-art has occurred. NASA has some plans to improve techniques but the effort should be increased in depth and scope.

6. Technical Plan:

A. Objectives

Provide a sampling and collection technique that is suitable for both men and women and is reliable and accurate.

B. Technical Approach

1. Survey analytical needs for sampling
2. Development sampling requirements from above
3. Determine reliability and accuracy of sampling methods
4. Select collection and sampling methods suitable for both sexes
5. Combine methods into one system suitable for both sexes and for generalized missions.
6. Develop prototype hardware to demonstrate feasibility of initial concept.
7. Refine concept and perform tests and evaluations of the final prototype.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	$150,000	$150,000
Equipment and Materials	25,000	25,000
Total	$175,000	$175,000

SRT M48

1. Item: Early Detection of Infectious Disease

2. Category: Advance Development

3. Technical Area/Panel: BioResearch

4. Status:

No method available presently for early detection of infectious disease.

5. Justification:

Spaceflight experience revealed impairment of crew performance by infections (viz., Apollo VII, VIII, and XIII). Infections also present crew-selection problems as noted on Apollo XIII. Infections can threaten mission accomplishment. Virus infections are known to have induced changes in the specific gravity distribution of peripheral lymphocytes. It is possible that a technique based on these changes could be developed to detect the early presence of disease.

6. Technical Plan:

A. Objectives

Develop and evaluate a method for the early detection of disease in potential crewmen to avoid inflight problems based on changes in lymphocyte specific gravity gradient.

B. Technical Approach

1. Determine correlation between viral infections and specific gravity distribution of lymphocytes.
2. Investigate specific gravity distribution of lymphocytes in normal and diseased individual.
3. Develop and automate equipment for measuring specific gravity distribution of lymphocytes.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	1	3
Funding		
Engineering	$50,000	$150,000
Equipment and Materials	25,000	100,000
Total	$75,000	$250,000

SRT M49

1. Item: Environmental Microbiology

2. Category: Advance Development

3. Technology Area/Panel: BioResearch

4. Status:

Prelaunch cleanliness requirements for spacecraft atmospheres and onboard equipment are not defined. The need for controlling cross-transmission and microbial buildup during fabrication and flight are not defined.

5. Justification:

The control of environmental microbiology involves expensive procedures and equipment. Currently, there are no satisfactory standards or rationale for establishing levels of contamination.

6. Technical Plan:

A. Objectives

To establish acceptable microbial criteria and determine means for maintaining them in Modular Space Station flights.

B. Technical Approach

1. Establish pretest contamination control requirements for manned tests.
2. Improve atmosphere monitoring methods.
3. Develop more quantitative bioassay methods for surface and subsystem contaminants.
4. Study microbial cross-transmission using tracer organisms.
5. Determine biodeteriorative effects on subsystems
6. Determine contamination from stored wastes using indicator organisms.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2	2
Funding		
Engineering	$100,000	$100,000
Equipment and Materials	10,000	20,000
Total	$110,000	$120,000

SRT M50

1. Item: Body Composition and Fluid Balance Methodology
2. Category: Advance Development
3. Technical Area/Panel: BioResearch
4. Status:

Current methods for measuring fluid compartments and lean body mass are difficult, complex and time consuming.

5. Justification:

Experience in space indicates that major problems exist in body composition adaptation to zero gravity. These changes also accompany confinement and disease. Adequate techniques for measuring these changes in orbit are required for Modular Space Station flights to help assure astronaut health and safety.

6. Technical Plan:

A. Objectives

Develop methods for measuring body composition and fluid balance which can be performed with relative ease in space.

B. Technical Approach

1. Investigate whole body impedance ratio as a potential method of body fluid balance measurement.
2. Compare results with those of other methods.
3. Design and develop equipment for whole body impedance ratio measurement.
4. Emphasize water balance analyses in fugure manned tests.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2	4
Funding		
Engineering	$100,000	$200,000
Equipment and Materials	20,000	25,000
Total	$120,000	$225,000

SRT M51

1. **Item: Potable Water Monitoring and Contamination Control**

2. **Category: Advance Development**

3. **Technology Area/Panel: BioResearch**

4. **Status:**

Methods for maintaining the sterility of water at required levels are unsatisfactory. Additionally, the effects of microbial by-products on the sterility of waters are unknown. Finally, the certification requirements/criteria should be re-evaluated and more realistic ones defined.

5. Justification:

It is crucial to crew health to maintain specified levels of sterility in potable water. These problems are acute in closed or partially closed systems. Therefore, adequate equipment and techniques must be developed to insure that appropriate sterility levels are maintained.

6. Technical Plan:

A. Objectives

To define acceptable means for maintaining required levels of sterility in potable water; to establish realistic requirements/criteria for potable water sterility.

B. Technical Approach

1. Define biocide development and distribution methodology.
2. Conduct research in nonchemical sterilization techniques.
3. Re-evaluate microbial criteria.
4. Accelerate rapid monitoring technology.
5. Investigate potential of microbial by-product impact on potability/safety.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	1.5	1
Funding		
Engineering	$ 75,000	$50,000
Equipment and Materials	$ 25,000	$25,000
Total	$100,000	$75,000

SRT M52

1. Item: Low-Level Environmental Stress Criteria

2. Category: Advance Development

3. Technology Area/Panel: BioResearch

4. Status:

Criteria have not been established for low-level environmental stresses which can be encountered in manned orbital systems and the potential for long-term accumulation of subtle effects is not defined. As a result, the requirements to control low-level stress in orbit are not defined.

5. Justification:

Most data regarding environmental stresses are derived from the effects of acute, intense exposures. It is important to know also the effects of low-level environmental stress which could adversely affect crew performance.

6. Technical Plan:

A. Objectives

To develop design criteria which will alleviate the adverse effects of low-level environmental stresses in orbit.

B. Technical Approach

Utilizing closed-loop simulator studies:

1. Identify potential low-level stressors in simulator environment.
2. Analyze effects of low-level stress.
3. Develop methods for precise measurement of small phsiological and biochemical changes.
4. Accumulate data on various environmental stresses.
5. Prepare handbook of low-level stress effects and design criteria to alleviate problems.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	$150,000	$150,000
Equipment and Materials	25,000	25,000
Total	$175,000	$175,000

SRT M53

1. Item: Atmospheric Constituent Requirements

2. Category: Advance Development

3. Technology Area/Panel: BioResearch

4. Status:

The atmospheric constituent requirements currently available are not mission-specific (i.e., too general). The impact of various gas mixtures combined with other mission-specific requirements has not been identified.

5. Justification:

Firm atmospheric constituent requirements are central to the development of life support equipment and provisions. These requirements should be based upon specific mission requirements/constraints such as mission duration, decompression hazard, fire/explosive hazards, EVA frequency, pressure suit compatibility, and bends risk criteria to assure maximum crew safety and cost-effective equipment development.

6. Technical Plan:

A. Objectives

Determine atmosphere requirements for a spectrum of missions.

B. Technical Approach

The recommended approach is to correlate mission duration, atmospheric composition required, decompression, hazards to determine cabin pressure requirements. Then, determine gas mixture for both high and low pressures. For high-pressure systems, consider the frequency of EVA decompression, pressure suit development, and bends risk criteria to ascertain whether 12 psi or 14.7 psi is required. For a low-pressure system, consider single vs mixed gases against fire/explosive safety requirements to determine whether 2.5 psi, 3.4 psi or 7 psi is required. Hypoxic cabins will be considered for some missions.

7. Resource Requirements:

	FY 1973
Manpower (man-yr)	1
Funding:	
Engineering	$50,000
Equipment and Materials	0
Total	$50,000

SRT M54

1. Item: Decompression Sickness Empirical Model

2. Category: Advance Development

3. Technology Area/Panel: BioResearch

4. Status:

Dysbarism prediction, prebreathing requirements and atmosphere equilibration are not currently systematized for aerospace application. Further, population risks and risk factors are not accurately defined.

5. Justification:

A systematic approach is needed to predict dysbarism problems, prebreathing requirements, and atmosphere equilibration for advance orbital systems in order to assure safe and efficient orbital operations.

6. Technical Plan:

A. Objectives

To provide a model for deriving decompression sickness potential for Modular Space Station missions, to establish a data bank to test and improve the model.

B. Technical Approach

1. Complete the development of the MDAC Decompression Sickness Model.
2. Establish a data bank of mission requirements, constraints and decompression sickness potential.
3. Test and improve the model by application of the data bank.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	1	2
Funding		
Engineering	$50,000	$100,000
Equipment and Materials	0	0
Total	$50,000	$100,000

SRT M55

1. Item: Wash Water Criteria

2. Category: Advance Development

3. Technology Area/Panel: BioResearch

4. Status:

No generally accepted standards currently exist for wash water concerning taste and smell, microbial contamination, chemical composition, conductivity and hardness.

5. Justification:

Wash water criteria are required to complete the development of water management systems for Modular Space Station systems.

6. Technical Plan:

A. Objectives

Establish acceptable standards/criteria for wash water.

B. Technical Approach

1. Establish preliminary standards for wash water.
2. Coordinate with National Academy of Science.
3. Investigate engineering capability for meeting criteria.
4. Determine crew acceptability in manned tests.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2	1
Funding		
Engineering	$100,000	$50,000
Equipment and Materials	0	0
Total	$100,000	$50,000

SRT M56

1. Item: Biological Specimen Container*

2. Category: Advanced Development

3. Technology Area/Panel: BioResearch

4. Status:

Present ground biological facilities exist for animal studies with viral and contagious organisms. These facilities and apparatus should be investigated for their applicability for modification to space use.

5. Justification:

Animal habitability studies are required as part of the cage development. Commonality in cage/container design should be stressed for compatibility with a common EC/LS manifold and cage rack system. Cages or growth chambers are required for small animals, plants, micro-organisms and invertebrates. In addition, specialized containers are required for preservation and storage of specimens with heating and cooling capability. Fluid nutrient and waste management and bioisolation problems will pace this activity.

6. Technical Plan:

The tasks associated with this item are to determine requirements for biological specimen containers and develop prototype designs.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	4	14	15	7
Funding				
Engineering	$200,000	$700,000	$ 750,000	$350,000
Equipment and Materials	150,000	150,000	250,000	150,000
Total	$350,000	$850,000	$1,000,000	$500,000

*Recommended for Growth Space Station application.

SRT M57

1. Item: Crew Task Allocation for Data and Experiment Operations

2. Category: Advance Development

3. Technical Area/Panel: BioEngineering

4. Status:

Although information on 1-g data processing is available, extrapolation to zero-g operations has not been systematically performed.

5. Justification:

Modular Space Station missions require realistic crew time allocations for data processing tasks (a significant portion of the work-day), and trade studies to determine the cost effective allocation of on-orbit functions should be accomplished. Further, contract studies and Apollo experience on crew/ computer interface have not been analyzed.

6. Technical Plan:

A. Objectives

Determine realistic crew functions and time allocations for data processing.

B. Technical Approach

1. Perform detailed analysis of existing information.
2. Conduct trade studies and cost analyses of variations in orbit vs ground and manned vs automated experiment operations and data interpretation and handling.
3. Validate findings in simulation studies.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	\$150,000	\$150,000
Equipment and Materials	50,000	25,000
Total	\$200,000	\$175,000

SRT M58

1. Item: Quantification and Measurement of Habitability

2. Category: Advance Development

3. Technological Area/Panel: BioEngineering

4. Status:

Subjective rating scales are available and have been used extensively; however, tools for objective measurements are not available.

5. Justification:

Techniques should be available for objectively evaluating habitability design features during the development of system design. Long-term confinement studies are impractical for development of quantitative data since the range of potential habitat variations are limited and the results are dependent on mission fidelity and crew motivation. Subjective ratings are not adequate since they are not amenable to development of functional relationships and they lack reliability and validity.

6. Technical Plan:

A. Objectives

Develop predictors (functional correlates) of habitability requirements which are observable to the experimenter, subject to quantitative measurement, apparent from short-duration study and independent of individual motivation.

B. Technical Approach

A three-phase study is recommended:

1. Develop quantitative measurement and measurement techniques.
2. Application of selected measurements to selected habitability futures.
3. Verify in long-term confinement studies.

7. **Resource Requirements:**

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	$150,000	$150,000
Equipment and Materials	25,000	25,000
Total	$175,000	$175,000

SRT M59

1. Item: Accommodations for Female Astronauts

2. Category: Advance Development

3. Technological Area/Panel: BioEngineering

4. Status:

Only limited data available on female anthropometry (e.g. Tektite) and habitability design requirements.

5. Justification:

Detailed requirements are required to design facilities which accommodate both male and female astronauts, as required by Space Station missions.

6. Technical Plan:

A. Objectives

Provide data regarding female anthropometry and habitability design requirements.

B. Technical Approach

1. Analyze requirements for habitability.
2. Determine appropriate tasks allocation.
3. Evaluate results in long-term confinement studies.
4. Develop and test prototype equipment.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	1	1
Funding		
Engineering	$50,000	$50,000
Equipment and Materials	25,000	25,000
Total	$75,000	$75,000

SRT M60

1. Item: EVA Requirements

2. Category: Advance Development

3. Technology Area/Panel: BioEngineering

4. Status:

Little data is available regarding EVA vs remote controlled tasks, therefore, appropriate trade studies cannot be performed.

5. Justification:

Space Station missions will undoubtedly require inspection, servicing, repair or replacement of parts of externally located equipment. It is not known in sufficient details whether or not these tasks should be performed through EVA or by remote control. The latter eliminates the need for costly expendables and removes a significant hazard but the cost in terms of time and equipment and the reliability are unknown.

6. Technical Plan:

A. Objectives

Determine cost effectiveness of manned EVA vs remote control for performing tasks external to the prime vehicle.

B. Technical Approach

1. Identify and define manned EVA vs remote activities.
2. Conduct simulation and analytic studies to compare EVA vs remote capabilities.
3. Develop prototype hardware (remote manipulators, mobility and restraint aids and life support) for test and evaluation.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2	2
Funding:		
Engineering	$100,000	$100,000
Equipment and Materials	50,000	50,000
Total	$150,000	$150,000

SRT M61

1. Item: On-Orbit Crew Performance Assessment

2. Category: Advance Development

3. Technology Area/Panel: BioEngineering

4. Status:

Preliminary techniques were developed and evaluated during the 90-day test at MDAC. The feasibility and validity of non-interference testing was established. No objective technique has been used in previous NASA programs and none is available for future ones.

Previous work in this area by MDAC includes measurement of crew activity using photo-cell sensors in the 60-day manned test and the NIPA (Non-Interference Performance Assessment) experiment on the 90-day manned test.

5. Justification:

A suitable means of assessing crew performance on Space Station missions is required to evaluate selection and training criteria and especially for improving system design. Two attractive techniques have been identified: (1) TV or motion picture film, and (2) voice records. The kinds of indicators in the video and audio records from the 90-day test are: (1) patterns of crew movement within the simulator, (2) changes in tempo, rhythm or variety of physical movements, (3) changes in frequency or intensity of voice patterns, (4) changes in speed of talking, (5) changes in vocabulary used.

6. Technical Plan:

A. Objectives

To develop equipment, procedures and techniques for non-obtrusively evaluating the crew in terms of task performance, emotional and psychological state (measurements of anxiety, hostility, motivation, morale, etc.) and group cohesiveness.

B. Technical Approach:

1. Analyze data from 90-day test (video and audio) for clues indicative of performance change.
2. Compare these data with other available data such as crew logs and questionnaire responses to determine if these were changes, what the changes were and the magnitude of change.
3. Develop experimental techniques for non-obtrusive assessment of crew performance.
4. Evaluate concepts in mockups and test situations.
5. Refine assessment technique for use in orbital systems.
6. Develop prototype system for test and evaluate purposes.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding		
Engineering	$150,000	$150,000
Equipment and Materials	50,000	25,000
Total	$200,000	$175,000

SRT M62

1. Item: On-Orbit Maintenance

2. Category: Advance Development

3. Technical Area/Panel: BioEngineering

4. Status:

Maintenance functions and maintenance design criteria are not generally established for future Space Station missions.

5. Justification:

Although DOD, for example, has long-established maintenance programs (regulations, Mil Specs, etc.), NASA has no such program. Much data is available from analytic and simulator studies (underwater, frictionless platforms) regarding zero-g maintenance capabilities and tool requirements but it has not been systematically evaluated and collated.

6. Technical Plan:

A. Objectives

Standardization of maintainability design, tools and support aids.

B. Technical Approach

1. Establish maintenance requirements and modes for a variety of future missions.
2. Develop maintainability design criteria.
3. Develop equipment and methodology for onboard technical data.
4. Standardize tools and support aids.
5. Verify equipment, procedures, and crew capabilities in simulation studies.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	3	3
Funding:		
Engineering	$150,000	$150,000
Equipment and Materials	50,000	25,000
Total	$200,000	$175,000

SRT M63

1. Item: Cargo Handling, Packaging, and Storage

2. Category: Advance Development

3. Technology Area/Panel: BioEngineering

4. Status:

Qualitative data on handling of specific sizes and weights is available and storage requirements have been defined in analytic studies. No data is available regarding on-orbit packaging and storage.

5. Justification:

Quantifiable data are required for cargo handling, packaging, and storing to complete design requirements for Space Station missions. Skylab storage growth experience reflects this need.

6. Technical Plan:

A. Objectives

Provide quantitative data regarding cargo handling procedures and define packaging and storage requirements and mechanical handling aids for future Space Station missions.

B. Technical Approach:

1. Perform simulation studies to develop parametric data on handling times and errors as a function of size, shape, and mass.
2. Develop cargo handling aids.
3. Establish design criteria.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	2	1
Funding		
Engineering	$100,000	$50,000
Equipment and Materials	50,000	0
Total	$150,000	$50,000

SRT M64

1. Item: Mass Determination Devices

2. Category: Advanced Development

3. User Technology Area/Panel: BioEngineering

4. Status:

Skylab device exists. This device or another type must be developed for determining masses of small samples.

5. Justification:

Extend Skylab mass determination device development to read to 0.1 mg. This is needed for physiologic studies on animals, plants, and other types of biology; if existing concepts prove unacceptable, a subsequent (near-parallel) effort of approximately equal size could result.

6. Technical Plan:

The tasks associated with this item are to study, develop, and verify performance of zero-g operable mass determination devices which would be capable of measuring small samples.

7. Resources Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	1	2
Funding		
Engineering	$ 50,000	$100,000
Equipment and Materials	50,000	100,000
Total	$100,000	$200,000

SRT M65

1. Item: Physiologic Monitoring Equipment

2. Category: Advanced Development

3. Technology Area/Panel: BioEngineering

4. Status:

IMBLMS, other studies and breadboard hardware is currently undergoing study and design. These efforts should be coordinated and integrated with planned programs.

5. Justification:

The various instruments required for physiologic monitoring of biological specimens are to a large extent available in ground-based designs. A feasibility study with prototype development is required for a large number of devices including:

- Dosimeter
- Scintillation Counter
- Impedance Pneumograph
- Implanted Sensors
- Oscillograph
- Potentiometric Recorders
- Bone Densitometer
- EMG, EEG, ECG Equipment
- Micro-transmitters

6. Technical Plan:

The tasks associated with this item are to develop and test prototype physiologic monitors necessary for the successful completion of bio-research planned for the Modular Space Station Project. IMBLMS equipment should be used when applicable.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	5	9	13	23
Funding				
Engineering	$ 250,000	$ 450,000	$ 650,000	$1,150,000
Equipment and Materials	750,000	1,550,000	3,350,000	4,850,000
Total	$1,000,000	$2,000,000	$4,000,000	$6,000,000

SRT M66

1. Item: Availability Prediction Method Verification (General Repair/ Maintenance Facility)

2. Category: Advanced Development

3. Technology Area/Panel: BioEngineering

4. Status:

Predictive analyses for system availability are developed and frequently used in manned space program studies. There are no operational systems available to verify the methodology.

5. Justification:

Spacecraft system operations must be tested by predictive analyses prior to launch as a means to verify that the design being developed will provide the desired performance. Verification of the availability prediction technique is desired prior to the actual development of new systems (Space Station, Shuttle, etc.). Airline line maintenance operations provide parametric data useful for this verification.

6. Technical Plan:

A. Objectives

Verify that an analytical prediction model using the empirical data, weighting factors, and administrative considerations of a line maintenance environment accurately represents mission performance.

B. Technical Approach

1. Observe airline line maintenance operations in order to collect and understand maintenance data applicable to availability predictions.
2. Revise the prediction model as required to represent the environment.
3. Iteratively exercise the model using the parameters. Correspondence between the predictive model and the actual performance measure provides the true understanding of the factors and parameters to be reflected in the Space Station model.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	1.5	3.4
Funding		
Engineering	$75,000	$170,000
Equipment and Materials	0	0
Total	$75,000	$170,000

SRT M67

1. Item: Water System Bacteriological Control and Monitoring

2. Category: Advanced Development

3. Technology Area/Panel: BioEnvironment

4. Status:

Chemical control of bacteria in water has been used in city and industrial water systems for decades. A wealth of data is available regarding bacteria kill effectiveness, chemical staying power, and acceptable levels regarding odor and taste. Much of this data is useful for development of a space-type system.

A simple chemical addition system was used on Project Apollo but many of the early attempts proved unsatisfactory because the chemical additives were not controlled adequately. Additionally, the tests were of short duration and the water purified was fuel cell water which was low in substrates.

Iodine addition is being considered for Skylab water purification, however, the stored water is ultrapure and will be very low in substrates. Essentially, present monitoring technology uses individual laboratory type chemical analysis for each measurement required. Some early prototype devices have been built which continuously monitor bacteria count. Bioluminescence and chemiluminescence are presently under development and show the greatest promise of providing a rapid and accurate determination of microbial levels to the low levels (maximum of 10 organisms/ml) required for Space Station mission.

5. Justification:

Bacteria control is necessary for potable water because bacteria growth will occur if even the slightest traces of substrate are present. Additionally, water recovery methods and filters do not always present a 100-percent barrier against bacteria and some carryover can occur. For these reasons, a positive means of bacteria control is needed in the potable water supply lines and tanks.

Pasteurization with 140°F temperature or higher is the only positive means which is currently developed sufficiently to be considered for a Space Station launched in 1980. Pasteurization is an effective control means; however, it possesses a number of drawbacks. Water sterility must be maintained not only in tanks but also in feedlines, coolers, distribution lines, valves, etc. Pasteurization is difficult to perform in many of these components since high temperature is not compatible with delivery temperatures. At best, a well-insulated and a complex recirculation loop is necessary, and the attendant heat loss to the cabin atmosphere represents a heat rejection penalty. Additionally, a heat source is required to raise the water storage temperature for pasteurization. A portion of this water must later be cooled for crew use.

Silver ion generators are well-developed but are only partially effective as a bacteria control means. Although the silver ions are effective against intestinal bacteria, they are not as effective against skin bacteria. An additional problem is the short staytime of the silver ions due to reaction with other materials in the water and plating out on surrounding surfaces.

Due to these factors, the silver ion generation must be supplemented by other methods of sterilization.

Most of the problems associated with pasteurization and silver ions are overcome by chemical sterilization. Both iodine and chlorine are very effective regarding kill ability and staytime. The major drawback to these chemicals is the difficulty of maintaining an optimum chemical concentration, i.e., high enough to control bacteria and low enough to prevent unacceptable taste and odor to the crew. Because of the long staytime of these chemicals, recirculation may not be required and tank and line insulation is eliminated. The total penalty associated with chemical sterilization is expected to be considerably less than for pasteurization, and the potential effectiveness of the technique is higher since bacteria kill capability can be maintained through the potable water loop.

The most important aspect of maintaining general health of the crew in the Space Station is maintaining control and detection of microbiological levels, particularly in the water supply. Monitoring to determine whether water is fit for human consumption is essential, because reclamation of condensate, wash water, and urine is required to maintain a water balance. No flight-type microbiological or water quality monitoring systems exist today, nor does agreement exist on the parameters to be measured to provide adequate determination of potability. However, studies have shown that monitoring of conductivity, organics, specific ions, and microorganisms indicates water quality.

Use of commercial laboratory techniques are unacceptable because of the crew time involved. A device which accomplishes these measurements relatively automatically and displays or records the results is required.

6. Technical Plan:

A. Objectives

The objective is to develop a bacteria control and monitoring system which uses chemical addition for water sterilization because it is simple, safe, effective, and acceptable to the crew. The technique must be effective when applied to the water composition anticipated from contemporary water recovery systems. Additionally, techniques for decontamination of the equipment must be developed.

B. Technical Approach

Available data will be scanned to identify potential chemical agents and data will be collected regarding bacteria kill effectiveness, chemical staying power and acceptable levels regarding odor and taste. A list of candidate chemicals will be selected and methods of agent addition and control will be identified. An assessment will be made for each technique regarding its promise from a total system standpoint and a technique will be selected for hardware development. If more than one technique shows equal potential, a second candidate will also be carried into a breadboard hardware phase. The selected approaches will be developed to the breadboard hardware stage and tested. At this stage, a prototype is developed of the most promising techniques and tested in an integrated simulator test.

Because chemical addition is a proven technique for Earth-bound application, development of a space prototype has a high probability of success for this SRT program.

Studies must be performed to establish which parameters must be measured to determine water potability. Potential automatic measuring techniques will be determined and the most promising will be selected for hardware development. Prototype monitors will then be developed and tested to verify reliability and performance.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	4	3
Funding		
Engineering	$200,000	$150,000
Equipment and Materials	100,000	50,000
Total	$300,000	$200,000

SRT M68

1. Item: Low Partial Pressure CO_2 Removal

2. Category: Advance Development

3. Technology Area/Panel: BioEnvironment

4. Status:

CO_2 removal systems using molecular sieve - silica gel are in the prototype stage and they have been run successfully in long-term tests. Hydrogen depolarizer/carbonation cells are at the development prototype stage and they have been bench tested for prolonged periods. As yet, the hydrogen depolerizer has not been run in an integrated long term test.

A prototype steam desorbed resin unit has been built and run in an integrated test.

5. Justification:

The current allowable CO_2 partial pressure is 3 mmHg which is near the lower limit of the capability for molecular sieve CO_2 removal systems. Maintaining this low level of CO_2 results in high weight and power penalties for molecular sieve systems and approaches must be developed which reduce these penalties.

A current program is underway by Life Systems to develop the hydrogen depolerizer concept, however, additional effort is recommended to pursue other promising techniques.

6. Technical Plan:

A. Objectives

The objective of this SRT effort is to develop a CO_2 control method which operates at low CO_2 partial pressures and reduces the vehicle penalty for CO_2 control.

B. Technical Approach

The technical approach is to continue development of promising CO_2 control methods. Special emphasis should be placed on those techniques which reduce power, weight, and complexity. The development should be carried to the point of long-term testing in a simulator. Methods selected for development should be applicable to both O_2 recovery or CO_2 dump.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	6	6	6
Funding			
Engineering	$300,000	$300,000	$300,000
Equipment and Materials	200,000	200,000	200,000
Total	$500,000	$500,000	$500,000

SRT M69

1. Item: Atmosphere Leak Location

2. Category: Advanced Development

3. Technology Area/Panel: BioEnvironment

4. Status:

Several prototype leak location devices have been built and tested based on acoustic sensors and thermisters. Additionally, there are many commercial instruments and techniques which are applicable.

5. Justification:

Losses of atmosphere to space from very small holes can be very significant (in the order of 2 lb/day for a hole 0.01 inches in diameter). A leak can easily be repaired once located. However, since the crew will be inside, location is very difficult. A method for quickly locating small penetrations, on the order of 0.001 inches in diameter, is needed. Failure of O-ring seals must also be detected.

Due to background noise, the acoustical approach has serious drawbacks. The device using thermisters to measure air velocity near the leak requires a high degree of wall access near the leakage area. Due to these short comings, effort is required to develop new leakage location devices which are not limited in application. The device should be applicable to structural and seal leakage due to failure or meteorite damage.

6. Technical Plan:

A. Objectives

The objective of this SRT effort is to develop leakage location devices which are simple, reliable, and efficient. They must be capable of application to any type of leak mechanism possible for the Space Station.

B. Technical Approach

Many techniques have been proposed (sonic detectors, O_2 sensors, transducers, paints, etc.) but little actual testing has been done to date. Analysis is needed to select a few promising techniques, followed by a test program.

7. Resource Requirements:

	FY 1973	FY 1974
Manpower (man-yr)	4	3
Funding		
Engineering	$200,000	$150,000
Equipment and Materials	100,000	50,000
Total	$300,000	$200,000

SRT M70

1. Item: Reverse Osmosis for Wash and Condensate Water Recovery

2. Category: Advance Development

3. Technology Area/Panel: BioEnvironment

4. Status:

The reverse osmosis unit is in the developmental prototype stage. A unit is being fabricated and tested by Chemtric Incorporated under Contract to NASA-MSC. This effort is intended to produce an engineering prototype for the Space Station Prototype Program (SSP).

Additional programs are being jointly sponsored by NASA and the Office of Saline Water (OSW) to develop better performing membranes. This effort is being directed largely to develop membranes which perform well at pasteurization temperatures (165°F).

5. Justification:

Reverse osmosis has the potential to recover condensate and wash water at very low weight and power penalties. Multifiltration, which is the major competitor, with reverse osmosis, requires large amounts of expendables if high quality recovered water is desired. On the other hand, small amounts of expendables are needed with reverse osmosis and the pumping power is low. Because reverse osmosis has the potential for low vehicle penalty, it is recommended as an SRT effort.

6. Technical Plan:

A. Objectives

The objective of this SRT effort is to develop a reverse osmosis prototype and verify its long-term performance in an integrated life support test. Recovery rates of 90 percent will be the design goal so that the penalty for water recovery from the residuum can be minimized. Maintaining a sterile system is a major objective of the effort since in the past bacterial growth within the wash water system has been a problem.

B. Technical Approach

The proposed effort consists of two distinct paths: (1) development of suitable membranes, and (2) development of an integrated reverse osmosis unit.

Both tasks are currently being performed under NASA and OSW Contract and no change to the current effort is being recommended. The membrane development task is concentrating on developing membranes which will operate satisfactorily at 165°F. This operating temperature is necessary to prevent bacteria growth within the reverse osmosis unit. Performance of state-of-the-art membranes degrade at pasteurization temperatures. Pasteurization is favored because biocides can cause skin irritations and they do not act sufficiently fast.

Development and testing of the prototype unit is necessary to determine if the membranes can be successfully integrated into a hardware package. The unit should be tested in an integrated life support test using crew produced wash water and condensate to create valid test conditions.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	4	6	4
Funding			
Engineering	$200,000	$300,000	$200,000
Equipment and Materials	100,000	100,000	100,000
Total	$300,000	$400,000	$300,000

SRT M71

1. Item: Solar Collector

2. Category: Advance Development

3. Technology Area/Panel: BioEnvironment

4. Status:

Preliminary designs for solar collectors have been completed on the Space Station and Space Station Prototype (SSP) programs. Computer simulation of the solar collector was also performed on the SSP program.

5. Justification:

The solar collector is an efficient and safe method for providing process heat in the temperature range from 200-400°F. However, if water is used as the heat transport fluid, the design may be susceptible to freezing or overpressure during loss of collector orientation or fluid circulation. These problems are believed rectifiable but SRT errort is required to assess the magnitude of the problem and to develop an acceptable design.

6. Technical Plan:

A. Objectives

The objective of this SRT effort is to determine to what extent freezing or overpressure conditions would occur in a solar collector. If these conditions are likely to occur, a design should be generated which eliminates or can tolerate freezing and overpressure.

B. Technical Approach

An assessment of freezing and overpressure problems is made by simulating the current Space Station design on a digital computer. Anticipated off-design point conditions are calculated to determine the degree of excursion of collector parameters. Next an assessment is made regarding the effect of the parameter excursions to determine if the design is tolerant. If solar collector damage occurs or recovery rate is low, redesign will be performed to arrive at an acceptable design. At this point, a representative model will be designed and fabricated and tested in a simulator to evaluate the design. If deficiencies occur, redesign will be performed to rectify the problems.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	4	4
Funding			
Engineering	$100,000	$200,000	$200,000
Equipment and Materials	25,000	100,000	100,000
Total	$125,000	$300,000	$300,000

SRT M72

1. Item: Radiator and Solar Collector Coatings

2. Category: Advance Development

3. Technology Area/Panel: BioEnvironment

4. Status:

A considerable amount of data is available on candidate coating performance and short term degradation due to solar radiation. Little is known on long term degradation due to solar radiation and effluent contamination.

5. Justification:

Vehicles flown in the past have been flown for short durations, up to about two weeks. The Skylab program will extend this duration considerably but the total mission time is far short of the 10 years or more required by the Space Station. Additionally, the Space Station radiator and solar collector will be subjected to different contamination environment because of vehicle subsystems and experiments unique to Space Station.

Because of this new contamination environment and the long life of the Space Station, SRT effort is required to assess radiator and solar collector coating degradation. Lack of this data could result in a loss of Space Station capability during later mission phases due to performance degradation.

6. Technical Plan:

A. Objectives

The objective of this SRT effort is to assess performance of existing coatings when subjected to a simulated Space Station environment. If all existing coatings degrade excessively, the effort will develop acceptable coatings.

B. Technical Approach

Existing coatings will be tested with a solar radiation and contamination environment envisioned for Space Station. The results will be compared to the degree of performance degradation acceptable for Space Station and a judgment will be made regarding the adequacy of existing coatings. If no existing coatings are adequate, a short study should be made to determine if coating development should be started or if alternate means such as radiator panel replacement or refurbishment should be considered. If the possibilities of developing a suitable coating appears high, the effort will proceed in that direction. The other alternate will consider modifications to the Space Station design or procedures to tolerate the anticipated coating degradation.

7. Resources Requirements:

	FY 1973	FY 1974
Manpower* (man-yr)	2	2
Funding*		
Engineering	$100,000	$100,000
Equipment and Materials	200,000	100,000
Total	$300,000	$200,000

*Values assume the existing coatings will be adequate.

SRT M73

1. Item: Non-Venting Fecal Collector

2. Category: Advance Development

3. Technology Area/Panel: BioEnvironment

4. Status:

A chemical fecal collector is being developed for Space Shuttle. Data from this unit is applicable to a chemical collector for Space Station.

A vacuum dump collector has been developed and tested during a long-term simulator test. Much of the design information on this unit can be used for a vacuum dry - no water dump technique. A vacuum pump, condensor, and storage tanks would be added to take the place of the space vacuum.

5. Justification:

Most of the candidate experiments for Space Station are susceptible to contamination by vented gases and particulate matter. The best developed and most promising fecal collectors and processors vent volatile fecal components overboard during the vacuum drying process. This vacuum drying approach can potentially contaminate experiment sensors and create a gaseous background which can obscure experiment results. A non-dumping fecal collector and processor must be developed to avoid interference with experiments.

6. Technical Plan:

A. Objectives

The object of this SRT effort is to develop a fecal collector and processor that dumps no material overboard. The design must represent minimum penalty to the program consistent with the no-dumping requirement. This means minimum power, weight, volume, and crew attention. Emphasis should be placed on safety and crew acceptance.

B. Technical Approach

Candidate techniques should be identified and evaluated regarding their ability to fulfill the program objectives. The most promising technique should then be selected and a development effort begun. If two candidate methods appear equally promising, two parallel efforts should be pursued and carried to the point where a winning concept can be identified. Long-term testing of the prototype should be performed in an integrated basis with a confined crew.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	3	3	2
Funding			
Engineering	$150,000	$150,000	$100,000
Equipment and Materials	50,000	250,000	50,000
Total	$200,000	$400,000	$150,000

SRT M74

1. Item: Trace Contaminant Control

2. Category: Advanced Development

3. Technology Area/Panel: BioEnvironment

4. Status:

Scattered data is available on contaminants identified in previous ground simulator tests but the sources and generation rates of many of the contaminants are unknown. Several trace contaminant control and monitoring devices have been built and operated in simulator tests, however, detailed test performance data is lacking.

5. Justification:

Because little detailed information is available on trace contaminant sources and generation rates, current control devices are over designed, resulting in excessive weight and power. More precise design data and performance of control techniques will facilitate a more optimum design. Because of the long associated development lead time, effort is required to develop acceptable contaminant monitoring devices.

6. Technical Plan:

A. Objectives

The objectives of this SRT effort is to identify in detail the type and generation rates of trace contaminants. Additionally, it will assess the performance capabilities of control devices.

B. Technical Approach

The approach is to test prototype equipment to ascertain the type and rates of generated contaminants. This type testing can be performed in conjunction with equipment development and acceptance testing. Biological data will be acquired through simulator tests. Other contaminants which are generated by cleaning fluids, or vehicle working fluids and structural materials will be identified also through simulator testing and previous space flights.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	2	2
Funding			
Engineering	$100,000	$100,000	$100,000
Equipment and Materials	50,000	50,000	50,000
Total	$150,000	$150,000	$150,000

SRT M75

1. Item: Orbital Calibration/Active Figure Control Techniques

2. Category: Advanced Development

3. Technology Area/Panel: Experiment Integration

4. Status:

Little work has been done on "how" man will calibrate instruments in orbit.

5. Justification:

In all the astronomical instruments, calibration and correction in orbit can be vital for optimum scientific results. Methods such as use of reference artificial sources, laser interferometer techniques with suitable feedback for active figure control should be studied.

6. Technical Plan:

The tasks associated with this item are to develop methods to calibrate optical instruments in orbit and compensate for component deterioration in the space environment. Simulation, high fidelity mockups, and underwater mockups can be utilized. Analogies to calibration of ground instruments are necessary to insure manned mission success.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	4	4	4	4
Funding				
Engineering	$200,000	$200,000	$200,000	$200,000
Equipment and Materials	50,000	300,000	550,000	550,000
Total	$250,000	$500,000	$750,000	$750,000

SRT M76

1. Item: Liquid-Handling Apparatus for Bioexperimentation

2. Category: Advanced Development

3. Technology Area/Panel: Experiment Integration

4. Status:

Technical liquid handling in Zero "G" has not been done except for short periods on Zero "G" aircraft flights and a very limited amount on Apollo.

5. Justification:

Most of the liquid handling apparatus required for Modular Space Station bio-experimentation has a ground-based counterpart, but major modifications are necessary before zero-g capability is attained. Services typical of those that will be used for analysis, transfer, storage, and processing include:

- Fraction Collector
- Fluid Transfer Equipment
- Electrophoresis
- Calorimeter
- Ultrasonic Cleaner
- Ion Exchange Column
- Water Bath
- Chromatograph (column/paper)
- Refractometer
- Lyophilizer
- Polarograph

6. Technical Plan:

The tasks associated with this item are to develop prototype liquid-handling apparatus for use in a zero-g environment and to test the equipment on precursor manned flights.

7. Resources Requirements.

	FY 1973	FY 1974	FY 1975
Manpower (man-yr)	2	11	11
Funding			
Engineering	$100,000	$550,000	$550,000
Equipment and Materials	150,000	200,000	300,000
Total	$250,000	$750,000	$850,000

SRT M77

1. Item: Automated Positioning and Retrieval of External Experiments

2. Category: Advanced Development

3. Technology Area/Panel: Experiment Integration

4. Status:

Some studies are in progress. Devices must be built, tested, and integrated into the Module Space Station design.

5. Justification:

A large amount of EVA time is required to position and retrieve contamination and exposure experiments external to the Modular Space Station. Methods of handling these experiments automatically and remotely via airlocks are needed.

6, Technical Plan:

The tasks associated with this item are to determine techniques and build a prototype for positioning experiments external to the station without EVA.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	1	3	10	10
Funding				
Engineering	$ 50,000	$150,000	$ 500,000	$ 500,000
Equipment and Materials	200,000	350,000	500,000	500,000
Total	$250,000	$500,000	$1,000,000	$1,000,000

SRT M78

1. Item: On-Orbit Cleaning, Recoating, Servicing and Calibration of Optical Elements

2. Category: Advanced Development

3. Technology Area/Panel: Experiment Integration

4. Status:

Current state-of-the-art for doing any servicing or calibration of optical elements in space is only in the conceptual stage. Much detailed work is necessary in order to fly the sophisticated experiments utilizing optics proposed for space.

5. Justification:

Many experiments involving optics are to be performed in space. It is desirable to service optics rather than replace them.

6. Technical Plan:

The tasks associated with this item are to determine feasibility of and methods for servicing optical devices in zero gravity.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	2	4	6	4
Funding				
Engineering	$100,000	$200,000	$300,000	$200,000
Equipment and Materials	200,000	300,000	400,000	300,000
Total	$300,000	$500,000	$700,000	$500,000

SRT M79

1. Item: Cryogenic Systems for Space Experiments

2. Category: Advanced Development

3. Technology Area/Panel: Experiment Integration

4. Status:

This technology must eventually be developed for Space Station subsystems and it is mandatory for sophisticated space experiments. Current designs for space use exist. These designs must be analyzed in detail, built and tested.

5. Justification:

Experiment requirements for cryogenics range from filling small dewars for Earth survey sensors through cooling of several hundred pounds of LHe for a superconducting magnet to the continuous cooling of an entire IR Telescope (1-meter aperture). Ground based systems are available, but must be qualified for space, including operational techniques to operate and restart after shutdown and warmup. Cryogenic fluid transfer systems must also be provided.

6. Technical Plan:

The tasks associated with this item are to define, build and test operational equipment needed to use cryogenic refrigeration systems in space use.

7. Resources Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	1	6	9	20
Funding				
Engineering	$ 50,000	$300,000	$ 450,000	$1,000,000
Equipment and Materials	300,000	450,000	650,000	$1,000,000
Total	$350,000	$750,000	$1,100,000	$2,000,000

SRT M80

1. Item: General Systems Technology

2. Category: Advanced Development

3. Technology Area/Panel: Management Techniques

4. Status:

Government and industry are exploring the availability of effective management techniques for controlling large, complex systems development. Current management practices have not been totally successful and frequently involve an undesirable degree of complicated detail.

The Space Station definition studies have evolved a direct and relatively simple approach to program management. The basis of this approach is the initial establishment of a program structure consisting of an inter-relating Technical Requirement Structure, a Management Structure and a Work Breakdown Structure (WBS) which are consistent with respect to leveling and the assignment of authority and responsibility. This, management technique emphasizes the top down structuring of performance and envelope requirements which then can be related to management responsibility, cost, and schedules.

5. Justification:

It is becoming evident that future space program development will be constrained by relatively fixed budget annual funding. This will impose upon management the rigorous necessity to control cost, optimize schedules, and above all, to develop a precise knowledge of required performance, its availability and relationship to cost. Structured program development, Technical Requirements Structure, WBS and Management Structure permits a rational orderly mechanism for identifying essential program performance, relating performance to cost and schedule management but in addition, facilitates the identification of impacts that may result from changes, reduction, or limited performance.

6. Technical Plan

A. Objectives

The proposed SRT activity is to explore the application of structural program development to several types of projected aerospace programs to further test its current advantages, and to investigate the ability of this management approach to the inter-relations of interacting programs. It is also necessary to extend the capability to the management of the total system including development acquisition and operations.

B. Technical Approach

The Space Station definition management techniques will be applied to the systemization of other programs scheduled for development in a similar time period. Of particular interest will be those programs related to the Space Station, which either support it or are supported by it. Inter-program relationships with respect to performance, development commonality, cost, and schedule relations of particular importance. The usefulness of this management approach during the development and operational phase of selected program needs substantial expansion and analyses. Quantitative performance parameters must be developed and assessed with respect to their proper level of application and the problems associated with over complexity of measurement parameters, technical measurement variance and its impact on program risk, cost and operational availability.

7. Resource Requirements:

	FY 1973	FY 1974	FY 1975	FY 1976
Manpower (man-yr)	4	6	8	10
Funding				
Engineering	$200,000	$300,000	$400,000	$500,000
Equipment and Materials	0	0	0	0
Total	$200,000	$300,000	$400,000	$500,000

3.3 SUPPORTING DEVELOPMENT

This category lists activities leading to the development of backup or alternate subsystems and components which should be concurrent with the major Modular Space Station development effort. Initiation of these activities during design phase (Phase C) should accelerate the baseline development schedule and will reduce program risk.

The SRT items identified for this category are summarized in Table 3-3. Detailed data for each of the Modular Space Station item following the table.

Table 3-3
SUPPORTING DEVELOPMENT SRT ITEMS

SRT Category, Number and Title		Technology Panel
M81.	Ku-Band Low Noise Receiving System	IS
M82.	Volatile Liquid Pressurization	C
M83.	Bellows Expulsion Tankage	C
M84.	Bio-Analytical Instrumentation	B-ENG
M85.	CO_2 Conversion	B-ENV
M86.	Water Electrolysis Unit Development	B-ENV
M87.	Photographic Film for Space Experiments	EI
M88.	Film Processor	EI

LEGEND:

- IS - Information Systems
- C - Control
- B-ENV - Bio-Environment
- EI - Experiment Integration

SRT M81

1. Item: K_u-Band Low Noise Receiving System
2. Category: Supporting Development
3. Technology Area/Panel: Information Systems
4. Status:

The performance of receiving systems utilizing directional antenna systems is commonly measured by a figure of merit known as the gain-to-temperature ratio (G/T_s). The antenna system gain (G) is often limited by physical constraints, therefore, in order to achieve the required receiving system performance the overall system noise temperature (T_s) must be reduced to the lowest level practical. In ground installations, the use of cryogenic cooling can and is used to achieve low system noise temperatures. However, cryogenic cooling is not practical for space applications. The two best candidates for space use appear to be the tunnel diode amplifier (TDA) and uncooled parametric amplifier.

The current state-of-the-art for TDA's is estimated to be 6-7 dB and several dB less for the uncooled paramp. The noise contribution due to the microwave components between the low-noise device and antenna can be considerable and could nullify the low-noise performance of the device.

5. Justification:

The system noise temperature including the external noise contribution of the Modular Space Station and data relay satellite K_u-Band receiving systems should be in the range of 1,000 - 1,200 degrees Kelvin. Higher system noise temperatures can only be compensated by increasing the size of antenna aperture or increasing the power output at the other end of the RF link, or both. There are no known development activities in this area.

6. Technical Plan:

<u>Objective</u>

The objective of this effort is to develop a low-noise K_u-Band receiving system integrated with an antenna feed having a system noise temperature not exceeding 900 degrees Kelvin, excluding the external noise contribution.

40

Technical Approach

The availability of several types of low-noise devices with the potential to satisfy the overall requirement would be ascertained. Tradeoff studies will be conducted comparing efficiency versus bandwidth for several type feed systems. This will include 4, 5, and 9 horn feeds, multimode and near field feeds. Selection of the type of monopulse technique to be utilized will also be made. Microstrip, stripline, and cavity or waveguide techniques for integrating the low-noise device and monopulse circuitry with the selected feed system will be evaluated. Several prototypes will then be fabricated and tested.

7. Resource Requirements

	FY 1976 (MID)	FY 1977
Manpower (man-yr)	2	2
Funding		
Engineering	$100,000	$100,000
Equipment and Materials	25,000	75,000
Total	$125,000	$175,000

SRT M82

1. Item: Volatile Liquid Pressurization

2. Category: Supporting Development

3. Technology Area/Panel: Control

4. Status:

Limited studies and tests have been made which show promise with regard to a reduction or elimination of pressurant resupply. Past studies have considered much higher flow rates and shorter duty cycles than required for the Space Station.

5. Justification:

The resupply of pressurant for the high-thrust propulsion system has inherent inefficiency and container weight is large. Volatile liquid pressurization could eliminate resupply and the necessary pressure controls and regulators resulting in a simpler more reliable system.

6. Technical Plan:

Perform analytical studies of the thermal control needs for liquids suitable for a manned Space Station. Perform feasibility tests of pressurization system using simulated propellants in a metal bellows positive expulsion tank.

7. Resource Requirements:

	FY 1976 (MID)	FY 1977
Manpower (man-yr)	1	2
Funding		
Engineering	$50,000	$100,000
Equipment and Materials	0	100,000
Total	$50,000	$200,000

SRT M83

1. Item: Bellows Expulsion Tankage

2. Category: Supporting Development

3. Technical Area/Panel: Control

4. Status:

Positive expulsion bellows tankage has been developed for storable propellants (MMH and N_2O_4) but not in a size large enough for the Space Station. These units have been qualified for severe environmental conditions but not for the long cycle life required by the Space Station.

5. Justification:

Propellant control during "O"-g operations is a requirement for the Space Station propulsion system. Positive expulsion bellows tankage offers a way to meet this requirement with an adequate life to eliminate the need for planned replacement or extensive flight testing.

6. Technical Plan:
   1. Develop positive expulsion bellows tankage of approximately 250 LBM (N_2H_4) capacity capable of withstanding 100-fill-and-drain cycles.
   2. Provide means of gaging propellant quantity, purging and safing propellant tank as required for replacement. This may be done by modification of existing design.

7. Resource Requirements:

	FY 1976 (Mid)	FY 1977	FY 1978
Manpower (man-yr)	2	3	2
Funding			
Engineering	\$100,000	\$150,000	\$100,000
Equipment and Materials	100,000	150,000	100,000
Total	\$200,000	\$300,000	\$200,000

SRT M84

1. Item: Bioanalytical Instrumentation

2. Category: Supporting Development

3. Technology Area/Panel: Bioengineering

4. Status:

Ground equipment will have to be studied, equipment modified, and/or designed and built for space use.

5. Justification:

The analytical instruments required for the anticipated biological experimentation have 1-g counterparts. A development effort is required to determine the feasibility and extend of modifications required for zero-g use with sample/man isolation. Typical devices include:

- Gas Chromatograph
- Spectrophotometer
- Responometer
- Drying Oven
- Muffle furnace
- Microscopes (general purpose and disecting)
- Micromanipulator
- Microtome (with cryostat)
- Autoclave

6. Technical Plan:

The tasks associated with this item are prototype development and test of various items necessary for analysis of products from bioexperiments.

7. Resource Requirements:

	FY 1976 (Mid)	FY 1977	FY 1978
Manpower (man-yr)	2	6	12
Funding			
Engineering	\$100,000	\$300,000	\$600,000
Equipment and Materials	400,000	450,000	400,000
Total	\$500,000	\$750,000	\$1,000,000

SRT M85

1. Item: CO_2 Conversion

2. SRT Category: Supporting Development

3. SRT Technology Area/Panel: Bioenvironment

4. Status:

Recent contracts from NASA/Langley have designed and developed a Bosch reduction subsystem. Long term integrated testing is now required to verify the design.

The solid electrolyte concept is not as well developed as the Bosch. However, completed tests include: a single cell test of 2,016 hours, a cell stack test exceeding 100 days and a 100-day disproportionation reactor test.

5. Justification:

CO_2 conversion was not selected for Modular Space Station because it did not meet the guideline for low cost. This decision is based on relatively low resupply costs and on a limited 10-year mission. Higher resupply costs or an extended mission duration would favor CO_2 conversion as an integral part of 0_2 recovery. Additionally, the Space Station trade could not consider the desirability of developing new concepts and systems for other vehicle applications such as interplanetary which favor 0_2 recovery.

Life support systems which dump CO_2 or methane gas to the surrounding space may not be acceptable for Space Station use because these gases interfere with experiments. One attractive way of preventing gas dumping overboard is to convert all crew CO_2 to solid carbon which can be easily returned to Earth. A second benefit comes from the water produced by the hydrogenation process which can be used to close the material loops on board the vehicle.

6. Technical Plan:

<u>Objectives</u>

The objective of this SRT effort is to develop a CO_2 hydrogenation concept which converts CO_2 to carbon to the flight prototype stage and demonstrate satisfactory long term performance in an integrated test.

Technical Approach

Current effort on the Bosch technique should be continued and the developed prototype should be tested in an integrated test at the earliest date. Parallel with this effort, other promising techniques should be developed and tested.

7. Resource Requirements:

	FY 1976 (Mid)	FY 1977	FY 1978
Manpower (man-yr)	3	5	2
Funding			
Engineering	$150, 000	$250, 000	$100, 000
Equipment and Materials	50, 000	100, 000	50, 000
Total	$200, 000	$350, 000	$150, 000

SRT M86

1. Item: Water Electrolysis Unit Development

2. SRT Category: Supporting Development

3. SRT Technology Area/Panel: Bioenvironment

4. Status:

Development is currently being performed on the four water electrolysis concepts listed below.

A. Solid Polymer Electrolyte
B. Circulating Electrolyte
C. Static Vapor Feed
D. Water Vapor

The General Electric Solid polymer electrolyte concept is funded by NASA/LRC. This concept has been bench tested for 250 days and a one-man breadboard system is currently being assembled and tested.

Both the circulating electrolyte and static vapor feed concepts are in the developmental prototype stage. Four man prototypes were tested in the 90-day MDAC Space Station simulator run and the results show additional development and testing are required.

A developmental prototype water vapor electrolysis unit has been built and successfully tested for 2,000 hours. Additional bench testing and vibration testing are planned.

5. Justification:

Although water electrolysis was not baselined for the Modular Space Station, it is recommended for supporting development. It was not chosen because it did not meet Space Station guidelines of low cost. However, if the launch cost goals for Shuttle are not met, oxygen recovery with water electrolysis is expected to become competitive. Additionally, experiment contamination considerations could favor 0_2 recovery. Further effort is needed in the area of experiment contamination due to overboard gas loss. If a need for no overboard dump becomes apparent, oxygen recovery becomes attractive. The Space Station trades which did not favor 0_2 recovery were based on a 10-year mission. If the mission is extended, 0_2 recovery is expected to become advantageous. Since water electrolysis would be an integral part of an O_2 recovery system, it is recommended for continued development.

6. Technical Plan:

Objective

The objective of this SRT effort is to develop a water electrolysis unit which meets performance requirements for long-term operation. Primary goals of the development are low weight, power, and crew time. High reliability and safety are important design guidelines.

Technical Approach

Concurrent development of the several candidate water electrolysis techniques is the favored technical approach. Emphasis should be placed on the most promising technique with the remaining candidates developed as backup alternates.

Testing in a long-term integrated test is essential when prototype bench testing proves satisfactory. This approach best simulates crew and equipment interface which water electrolysis units will encounter in a flight program.

7. Resource Requirements:

	FY 1976 (Mid)	FY 1977	FY 1978
Manpower (man-yr)	6	6	6
Funding			
Engineering	$300,000	$300,000	$300,000
Equipment and Materials	100,000	100,000	100,000
Total	$400,000	$400,000	$400,000

SRT M87

1. Item: Photographic Film for Space Experiments
2. Category: Supporting Development
3. Technology Area/Panel: Experiment Integration
4. Status:

Much has been done on this problem, the data must be pulled together and analyzed. Proposed solutions must be tested for applicability to the Space Station.

5. Justification:

The long-term effects of exposure to vacuum, temperature ionization, and radiation environment on film must be evaluated and the optimum film and use with various instruments selected. The tradeoff between high optical sensitivity and low response to radiation should be investigated. With this tradeoff made, special techniques such as delayed sensitization, post-exposure desensitization, film freezing and the need for on-orbit development, scan, digitization, and transmission to Earth can be determined.

6. Technical Plan:

The tasks associated with this item are to investigate film for space usage and propose and test methods for more efficient utilization of film.

7. Resources Requirements:

	FY 1976 (Mid)	FY 1977	FY 1978
Manpower (man-yr)	3	10	11
Funding			
Engineering	$150,000	$500,000	$550,000
Equipment and Materials	100,000	250,000	300,000
Total	$250,000	$750,000	$850,000

SRT M88

1. Item: Film Processor

2. Category: Supporting Development

3. Technology Area/Panel: Experiment Integration

4. Status:

Present state-of-the-art of spray technique film processing is suitable for zero "G". The development required is in handling of films, fluids and developing by products. In zero "G" the contingency for possible escaping of toxic gases and fluids must be taken into account.

5. Justification:

System or systems should process black and white, color, and infrared film with resultant products of archival quality. Techniques should constitute an advancement over state-of-the-art saturated web techniques.

6. Technical Plan:

The tasks associated with this item are to provide a prototype device for zero-g film developing by redesigning of commercial or military equipment.

7. Resources Requirements:

	FY 1976 (Mid)	FY 1977	FY 1978
Manpower (man-yr)	3	7	5
Funding			
Engineering	$150,000	$350,000	$250,000
Equipment and Materials	100,000	400,000	250,000
Total	$250,000	$750,000	$500,000

Section 4
CONCLUSIONS

The identification of the Modular Space Station Project SRT has resulted in:

A. Eighty-eight SRT items identified and described.

B. Four of the eighty-eight items are recommended for incorporation into the planning activities for the Growth version of the Modular Space Station (GSS).

C. Recommendation for assessment of all SRT items to identify program-critical items.

D. Recommendation for additional feasibility and exploratory-type studies to be initiated on the items deemed critical to the program in order to highlight and expose critical development problems. Adequate time exists to do these studies, since Phase C is not scheduled until FY 1976.

It should be made clear that the probability of accomplishing the Modular Space Station Program (Phases C and D) in the time scale indicated in Figure 1-1 is predicted on accomplishing each of the SRT items within its indicated time frame. In the event that these SRT items are not accomplished, or if they are achieved outside their allocated time frames, the probability of achieving the program milestones is very low.